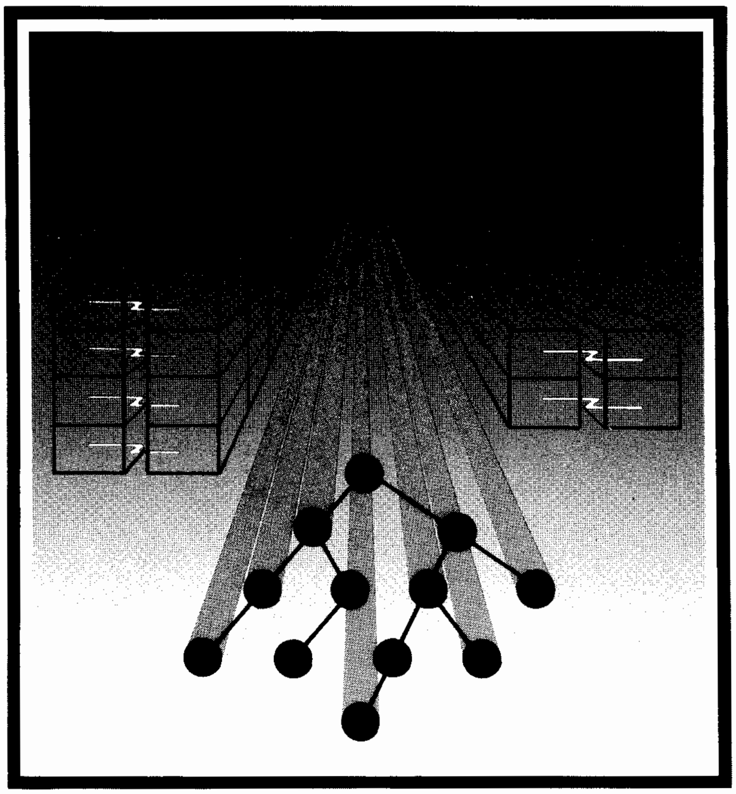
HP Computer Systems

Monte Carlo Simulation Utilities

For the HP 9845



HEWLETT PACKARD

Monte Carlo Simulation Utilities

HP System 45 Desktop Computer

Hewlett-Packard Desktop Computer Division
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"Almost all good computer programs contain at least one random-number generator."

Knuth, The Art of Computer Programming, Vol.2, p.157

"Anyone who considers arithmetical methods of producing random digits is, of course, in a state of sin."

John Von Neumann (1951)

Introduction

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Introduction

Description

The programs in this software package are meant primarily as a library of utility routines to be combined with the user's own programs. Hence, each routine is set up as an independent, modular unit with a standard set of input and output parameters. These subprograms contain no actual inputs or outputs, with the exception of error messages.

With each routine, the package provides a general-purpose front-end driver. In some cases, such as the Spectral and Run tests, the driver plus the routine make sense as a stand-alone unit. In other cases, such as the various random number deviates, the drivers are simply meant to introduce the user to the subprogram itself.

The software package **does not** establish the printers or the mass storage devices. It is the user's responsibility to select the printer and mass storage device **before** using any of these routines.

SYSTEM CONFIGURATION:

Necessary:

9845B Desktop Computer

Option 560 -	Thermal line printer (or an external printer)
09845-15160	Monte Carlo Simulation Utilities Software Pack
09845-15161	Monte Carlo Simulation Utilities Manual
09845-15164	Goodness-of-Fit Cartridge
09845-15165	Random Number Cartridge

Optional:

Option 204 –	187K bytes of Read/Write memory
Option 205 –	318K bytes of Read/Write memory
Option 206 –	448K bytes of Read/Write memory
Option 312 –	I/O ROM for data entry from external devices
Option 311 –	Graphics ROM
Option 600 –	Secondary tape transport
Option 700 –	Graphics Display Subsystem
9872A –	External plotter
9885M –	Flexible Disk Drive (requires Option 313 – Mass Storage ROM)
7900 Series –	Hard Disc (requires Option 313 – Mass Storage ROM and 98041A Disc Interface)

Operating Instructions

Operating Instructions

General Instructions

How Do I Load A Stand Alone Program?

1. Insert the Random Number cartridge into the tape transport.
2. None of the drivers ask for the desired printer or mass storage device. This must be set by the user from the keyboard.
3. Type: LOAD "File name",10
   Press: EXECUTE.
4. At this point, appropriate inputs are requested, computations are performed, and the results are printed or saved on a mass storage device.

How Do I Link One Of The Utility Subprograms Onto My Program?

Each program file has a driver and then one or more subprograms. If you want to incorporate just one of these subprograms into your routine, how do you do it?

The entire file needs to be loaded into memory first, and then the particular subprogram needs to be saved in a temporary file. Finally, after you have written your own code, you can link the temporary file containing the desired subprogram on after your code.

1. Insert the Random Number cartridge into the tape transport.
2. Type: LOAD "File name"
   Press: EXECUTE
3. After the program has been loaded,
   Type: EDITLINE
   Press: EXECUTE.

4. At this point, the screen looks as follows:

```
10  Beginning of driver program.
20      .
        .
        .            Driver program
        .
    END
        .
        .
        .
100 SUB Sub_to_be_linked
        .
        .
        .
    SUBEND
```

5. If subprogram Sub_to_be_linked is the one desired and it goes from line 100 to line 500, then
   Type: SAVE "TEMP",100,500
   PRESS: EXECUTE.
6. Type: SCRATCH (Don't type SCRATCH A. This will erase the binary.)
   Press: EXECUTE.
7. After you enter your program into memory, for this example assume that the last line of your code is line 2500. Then
   Type: LINK "TEMP",2510
   Press: EXECUTE.
8. The desired subprogram is then linked on behind your routine.

HOW DO I INCORPORATE THE BINARY ROUTINES INTO MY OWN PROGRAM?

Suppose you write your own routine and want to use the binary random number generator IRND. How is this done?

A binary program must first be loaded into memory before these statements can be used.

1. Type: LOAD BIN "RANDOM"
   Press: EXECUTE.
2. At this point, you may enter your program.

After the program has been entered into memory, how do you save it? There are two possibilities.

1. Type: STORE "File name"
   Press: EXECUTE.

The binary program is stored away with your program. Each time it is brought back into memory, the binary automatically comes with it.

or

2. Type: SAVE "File name"
   Press: EXECUTE.

The binary program will NOT be stored away. Each time the program is to be used, the binary program MUST be loaded first.

Special Considerations

1. All the programs in this package have been set up using the random number generator IRND. This may be replaced by either RND or the super random generator contained in RSUPER.
2. You now have three different random number generators at your disposal.

- IRND: a linear congruential generator. (See Appendix II for further details.)
- RND: a randomly generated generator. (See Appendix I for further details.)
- SUPER: a combination generator. (See "RSUPER' for further details.)

It is strongly suggested that any serious Monte Carlo simulation should be run with at least two of these different generators.

3. This package is meant to provide a set of subprogram utilities which you can combine to meet your particular needs. Each utility may be viewed as an independent modular unit. This allows you to combine these building blocks into your own program.
4. In order to get a feel for how each utility works and, in the case of the various generators, how much confidence you can place in them, driver routines have been provided. So, it is suggested that you first use these driver programs as is, and then later adapt them to your particular need.

5. In order to allow you the most flexibility, no references are made to printers or mass storage devices. Hence, to have a particular program run from a floppy disk having select code 8 and have all information printed on the CRT, you would type in the following before running your program:

   1. a. Type: MASS STORAGE IS ":F8"
      b. Press: EXECUTE
   2. a. Type: PRINTER IS 16
      b. Press: EXECUTE

6. Each of the driver programs for the random deviates allows you to:

   1. generate a set of random numbers to be printed or saved on a mass storage device.

      or

   2. get a feeling for the quality of the generator by running through some randomly generated tests.

7. There may be occasions where you will not have enough memory to store all the random numbers you would like to have. A number of possible tricks are available to you:

   a. Presently all deviates are set up in full precision arrays. Can you store the deviates in an integer or short precision array? Where a full precision array requires 8 bytes per number, a short precision array needs only 4, and an integer only 2. Care must be taken here to dimension your array using an INTEGER or SHORT statement rather than a DIM. Also, the parameters in the SUB statement must be changed to INTEGER or SHORT.

   b. Can you generate and use the random numbers in a partitioned fashion? For example, generate 1000 deviates, use them; generate 1000 more, use them; etc.

   c. If b is not possible, can you make use of your mass storage device to recall the deviates as you need them? For example:

      i. generate 1000 deviates; store them; generate 1000 more; store them; etc.

      ii. bring first 1000 deviates into memory; use them; bring next 1000 in; use them; etc.

8. Entering a value of 0, or 16 for the printer's select code automatically causes the program to skip over the question requesting the printer's bus address.

General References

1. Camp, Warren V. and Lewis, T.G., "Implementing a Pseudo-Random Number Generator on a Minicomputer", IEEE Transactions on Software Engineering, May, 1977.
2. Knuth, Donald E., The Art of Computer Programming, Volume 2: Seminumerical Algorithms, Addison-Wesley, Reading, Mass., 1969.
3. Learmonth, J. and Lewis, P.A.W., "Naval Postgraduate School Random Number Generator Package LLRANDOM", Naval Postgraduate School, Monterey, Calif., 1973.
4. Learmonth, J. and Lewis, P.A.W., "Statistical Tests of Some Widely Used and Recently Proposed Uniform Random Number Generators", Naval Postgraduate School, Monterey, Calif., 1973.
5. MacLauren, M.D. and Marsaglia, G., "Uniform Random Number Generators", JACM 12, Jan. 1965, p. 83-89.
6. Marsaglia, G. and Bray, T.A., "One-line Random Number Generators and Their Use in Combinations", CACM, Vol. II, 1968, p. 757-759.
7. Musyck, E., "Search For a Perfect Generator of Random Numbers", Studiecentrum Voor Kernenergie, E. Plaskylaan 144, Brussels 4, Belgium, January, 1977.
8. Reddy, Y.V., "PL/I Process Generators", SIMULETTER, Vol. III, Oct. 1976, p. 25-29.
9. Wheeler, Robert E., "Random Variable Generators", SIMULETTER, Vol. III, Oct. 1976, p. 16-23.

Interface Specifications for Binary Routines

Interface Specifications for Binary Routines

All binary commands can be either implemented under program control or executed directly from the keyboard.

The first set of statements is meant for the general user:

IRND X

- X a full precision number.
- Input is ignored.
- On output, X contains a uniformly generated random number between 0 and 1.
- See Appendix II for details on how IRND was developed.

SEED Seed

- Seed a full precision number.
- Resets the initial seed for the generator to Seed. Seed is transformed into a number in the range between 0 and 1 before use.
- This allows you to duplicate your experiment by using the same initial seed repeatedly.

The second set of statements is meant for a more sophisticated user.

The uniform random number generator uses the following theoretical model:

Let S(I) be the Ith randomly generated number and
S(I+1) be the (Ith + 1).

Then S(I+1)=(A * S(I) + C) MOD M

where A and C are appropriately chosen constants and M is the word size of the computer, in this case 10∧12.

In the binary, the values of A and C are based on some standard theoretical considerations. (See Appendix II.) The following two statements allow you to change these values. This means a new uniform random number generator is produced.

ACOEF X

- X a full precision number.
- Resets the value of coefficient A in the above formula to X.
- The value of X is left unchanged.
- X must be chosen with great care. It must be a 12 digit whole number based on some theoretical considerations (See Appendix II). Unpredictable results will occur if this caution is not followed.

CCOEF X

- X a full precision number.
- Resets the value of constant C in the above formula to X.
- The value of X is left unchanged.

Random Number Generators in BASIC

Random Number Generators in BASIC

Subprograms with optional drivers are provided to generate random deviates on some standard statistical distributions.

The subprograms have been set up as independent modules. Hence, it is quite simple to use these routines in your own programs. Choose values for the required input parameters, call the subprogram and the resulting outputs are returned to you.

Optional drivers have also been set up for your use. In general, the drivers: i) allow you to directly generate a set of deviates to be printed or saved on a mass storage device; and ii) provide the ability to check out the particular generator through the use of some standard tests in order to get a feel for the quality of the deviates produced.

(RBETA)
Random Numbers Generated From a Beta Distribution

(RBETA) Random Numbers Generated from a Beta Distribution

Description

Given a Beta distribution with V1 and V2 degrees of freedom respectively, this subprogram generates a set of random deviates.

File Name

"RBETA"

Calling Syntax

CALL Random_beta (N,V1,V2,X(*))

Input Parameters

N	number of deviates desired.
V1, V2	degrees of freedom on the Beta distribution.

Output Parameters

X(*)	array of dimension (1:N) containing the N deviates.

Algorithm

This routine generates deviates for the beta distribution with v1, v2 degrees of freedom. The method used is valid for both integer and non-integer v1 and v2:

1. Generate uniform random deviates u1 and u2.
2. Set y1=u1∧(2/v1); y2=u2∧(2/v2), repeating this process until finding y1+y2<=1.
3. Then x=y1/(y1+y2).

Reference

1. Knuth, Donald E., The Art of Computer Programming, Volume 2 (Seminumerical Algorithms), Reading, Mass.: Addison-Wesley, 1969, p. 115.

Instructions

1. Insert the RANDOM NUMBER cartridge with the machine turned on.
2. a. Type: LOAD "RBETA",10
   b. Press: EXECUTE
3. The title "RANDOM BETA DEVIATES" will be printed along with the possible ways of using the program.
4. When "ENTER YOUR CHOICE. [EITHER 1 or 2]" is displayed:

   a. Enter 1 if you want to directly generate a set of deviates.

   b. Press: CONT

   c. Go to 8.

   or

   a. Enter 2 if you would like to check through some randomly generated examples.

   b. Press: CONT

   c. Go to 5.

5. Default values are supplied for the size of the sets of deviates, and the Beta parameters.

   a. If the default values are satisfactory, simply press: CONT

   or

   a. Change the values as desired.

   b. Press: CONT

6. A set of deviates is produced for each pair of parameters. The starting seed, mean, variance and standard deviation are printed as well as the expected mean and variance.
7. When "WOULD YOU LIKE TO CONSIDER A PARTICULAR DATA SET? (Y/N)" is displayed:

   a. Enter Y if you would like to generate a particular set to be printed out or saved on a mass storage device.

   b. Press CONT

   c. Go to 8.

   or

   a. Enter N if no particular set is desired.

   b. Press: CONT

   c. At this point, the program is terminated.

8. When "ENTER VALUES FOR THE SIZE OF THE SET, SEED, V1, V2, E.G., 10,PI,3,5" is displayed:

   a. Enter values for the size of the set, the starting seed, and the Beta parameters.

   b. Press: CONT

9. When "WOULD YOU LIKE A PRINTOUT OF THE DATA? (Y/N)" is displayed:

   a. Enter Y if a printout is desired.

   b. Press: CONT

   c. Go to 10.

   or

   a. Enter N if a printout is not desired.

   b. Press: CONT

   c. Go to 12.

10. When "ENTER THE SELECT CODE OF THE PRINTER" is displayed:

    a. Enter the select code of the printer.

    b. Press: CONT

11. When "ENTER THE BUS ADDRESS OF THE PRINTER" is displayed:

    a. Enter the bus address of the printer.

    b. Press: CONT

    c. The data set is then printed out on the appropriate device.

12. When "WOULD YOU LIKE TO SAVE THE DATA SET? (Y/N)" is displayed:

    a. Enter Y if you would like it saved.

    b. Press: CONT

    c. Go to 13.

    or

    a. Enter N if you would not like it saved.

    b. Press: CONT

    c. The program is terminated at this point.

13. When “ENTER FILE NAME. FOR EXAMPLE: File:T14 OR DATA:F8” is displayed:

    a. Enter the desired file name.

    b. Press: CONT

    c. The data set is saved on your mass storage device as a vector and the program is terminated.

```
                          RANDOM BETA DEVIATES

   This program generates sets of Beta (V1,V2) random deviates.  You may use
the program in two ways:

    1. Directly generate a set of deviates to be printed or saved on a mass
       storage device.

    2. Check through some randomly generated tests in order to get a feel for
       the quality of the deviates produced.  You would then have the option
       to create your own data set.


   This program generates sets of Beta (V1,V2) random deviates.  It also
compares the resulting data with the theoretical expectations.  In particular,
given degrees of freedom V1 and V2, the mean and variance of each set of Beta
random numbers is calculated.

     The expected value of the mean is:  V1/(V1+V2).
     The expected value of the variance is:  V1*V2/[(V1+V2+1)*(V1+V2)^2].

The program is set up using the following default values:

   1. 100 deviates will be generated for each set of Beta parameters.
   2. Values for V1 and V2, the Beta parameters, are set at .50, 2.00, and 5.00.
   3. Results printed are:
        - mean, expected mean, and standard deviation for each set.
        - variance and expected variance for each set.
   Default values may be changed from the keyboard as they come up.

# OF RANDOM DEVIATES: 1000
DEGREES OF FREEDOM (V1): 0.50, 2.00, 5.00
DEGREES OF FREEDOM (V2): 0.50, 2.00, 5.00


Number:  1000

      Seed:    .292190093254           V1:     .50                  V2:    .50
      Mean:    .523          Expected Mean:    .500      Standard Dev.:    .406
  Variance:    .165      Expected Variance:    .125

      Seed:    .731868426712           V1:     .50                  V2:   2.00
      Mean:    .210          Expected Mean:    .200      Standard Dev.:    .270
  Variance:    .073      Expected Variance:    .046
```

```
     Seed:    .501346863484           V1:     .50                  V2:  5.00
     Mean:    .096          Expected Mean:    .091    Standard Dev.:    .151
 Variance:    .023      Expected Variance:    .013

     Seed:    .632712189059           V1:    2.00                  V2:   .50
     Mean:    .797          Expected Mean:    .800    Standard Dev.:    .265
 Variance:    .071      Expected Variance:    .046

     Seed:    .110950998353           V1:    2.00                  V2:  2.00
     Mean:    .502          Expected Mean:    .500    Standard Dev.:    .290
 Variance:    .084      Expected Variance:    .050

     Seed:    .309789614978           V1:    2.00                  V2:  5.00
     Mean:    .293          Expected Mean:    .286    Standard Dev.:    .214
 Variance:    .046      Expected Variance:    .026

     Seed:    .533066196490           V1:    5.00                  V2:   .50
```

```
     Mean:    .908          Expected Mean:    .909    Standard Dev.:    .155
 Variance:    .024      Expected Variance:    .013

     Seed:    .308671253619           V1:    5.00                  V2:  2.00
     Mean:    .715          Expected Mean:    .714    Standard Dev.:    .211
 Variance:    .044      Expected Variance:    .026

     Seed:    .592524293566           V1:    5.00                  V2:  5.00
     Mean:    .493          Expected Mean:    .500    Standard Dev.:    .206
 Variance:    .043      Expected Variance:    .023
```

At this point, you may select a particular data set which you can have printed out or saved on a mass storage device. You will be required to enter the following values: the size of the data set, the starting seed, and the Beta parameters, V1 and V2. For want of a better seed, PI is an excellent choice!

<u>BETA DEVIATES:</u>

Seed: .017453292520   V1:   3.0000   V2:   5.0000

I	X(I)	X(I+1)	X(I+2)	X(I+3)	X(I+4)
1	.542202	.138571	.441458	.540076	.367385
6	.547167	.314301	.318138	.238096	.634416
11	.143855	.295088	.286629	.043278	.282911
16	.145980	.879115	.461297	.201152	.444524
21	.203289	.265061	.420664	.072694	.239889

(RBINOM)
Random Integers Generated From a Binomial Distribution (T,P)

(RBINOM)
Random Integers Generated From a Binomial Distribution (T,P)

Description

Given that some event occurs with probability P and that we carry out T independent trials, this subprogram generates a set of integers with the binomial distribution (T,P).

File Name

"RBINOM"

Calling Syntax

CALL Random_binomial (N,P,T,X(*))

Input Parameters

N	number of deviates desired.
P	probability of the event occurring.
T	number of independent trials.

Output Parameters

X(*)	array of dimension (1:N) containing integers randomly generated for the number of occurrences.

Algorithm

Given T and P:

1. Set Sum=0.
2. For I=1 to T.
3. Generate a uniform random deviate U.
4. If U < = P then Sum=Sum+1.
5. Next I.
6. The binomial deviate is equal to Sum.

Reference

1. Reddy, Y.V., "PL/I Process Generators", SIMULETTER, Vol. III, Oct. 1976, p. 25-26.

Instructions

1. Insert the RANDOM NUMBER cartridge with the machine turned on.
2. a. Type: LOAD "RBINOM",10
   b. Press: EXECUTE
3. The title "RANDOM BINOMIAL DEVIATES" is printed along with the options available to you in the program.
4. When "ENTER YOUR CHOICE. [EITHER 1 or 2]" is displayed:

   a. Enter 1 if you want to directly generate a set of deviates.

   b. Press: CONT

   c. Go to 8.

   or

   a. Enter 2 if you would like to check through some randomly generated examples.

   b. Press: CONT

   c. Go to 5.

5. Default values are supplied for the size of the sets of deviates, and the probabilities.

   a. If the default values are satisfactory, simply press: CONT

   or

   a. Change the values as desired.

   b. Press: CONT

6. A set of deviates is produced for each combination of given probability P and number of trials T. After each data set is generated, the starting seed, the mean, variance and the standard deviation are printed as well as the theoretical expected mean and variance.
7. When "WOULD YOU LIKE TO CONSIDER A PARTICULAR DATA SET? (Y/N)" is displayed:

   a. Enter Y if you would like to generate a particular set to be printed out or saved on a mass storage device.

   b. Press: CONT

   or

   a. Enter N if no particular set is desired.

   b. Press: CONT

   c. At this point, the program is terminated.

8. When "ENTER VALUES FOR THE SIZE OF THE SET, SEED, TRIALS, PROB. E.G.100, PI,10,.8" is displayed:

   a. Enter values for the size of the set, the starting seed, the number of trials and the probability.

   b. Press: CONT

9. After the data set has been created, the prompt: "WOULD YOU LIKE A PRINTOUT OF THE DATA? (Y/N)" is displayed:

   a. Enter Y if a printout is desired.

   b. Press: CONT

   c. Go to 10.

   or

   a. Enter N if a printout is not desired.

   b. Press: CONT

   c. Go to 12.

10. When "ENTER THE SELECT CODE OF THE PRINTER" is displayed:

    a. Enter the select code of the printer.

    b. Press: CONT

11. When "ENTER THE BUS ADDRESS OF THE PRINTER" is displayed

    a. Enter the bus address of the printer.

    b. Press: CONT

12. When "WOULD YOU LIKE TO SAVE THE DATA SET? (Y/N)" is displayed:

    a. Enter Y if you would like it saved.

    b. Press: CONT

    c. Go to 13.

    or

    a. Enter N if you would not like it saved.

    b. Press: CONT

    c. At this point, the program terminates.

13. When "ENTER FILE NAME. FOR EXAMPLE, File:T14 OR DATA:F8" is displayed:

    a. Enter the desired file name.

    b. Press: CONT

    c. The data set is saved on your mass storage device as a vector and the program ends.

RANDOM BINOMIAL DEVIATES

This program generates sets of Binomial (T,P) random deviates. You may use the program in two ways:

1. Directly generate a set of deviates to be printed or saved on a mass storage device.

2. Check through some randomly generated tests in order to get a feel for the quality of the deviates produced. You would then have the option to create your own data set.

This program generates sets of Binomial (T,P) random deviates. It also compares the resulting data with the theoretical expectations. In particular, given the number of independent trials T, and the probability P,the mean and variance of each set of Binomial random numbers is calculated.

The expected value of the mean is: T*P.
The expected value of the variance is: T*P*(1-P).

The program is set up using the following default values:

1. 100 deviates will be generated for each set of Binomial parameters.
2. Values for T, the number of trials, are set at 5, 16 and 30.
3. Values for P, the probability, are set at 0.1, 0.5, and 0.9.
4. Results printed are:
   - mean, expected mean, and standard deviation for each set.
   - variance and expected variance for each set.

Default values may be changed from the keyboard as they come up.

```
# OF RANDOM DEVIATES: 1000
# OF INDEPENDENT TRIALS: 5, 16 ,30
PROBABILITIES: 0.1, 0.5, 0.9


Number:  1000

      Seed:    .072190093205        Trails:   5.00              Prob:    .10
      Mean:    .511           Expected Mean:    .500   Standard Dev.:    .677
  Variance:    .458       Expected Variance:    .450

      Seed:    .711868385227        Trails:   5.00              Prob:    .50
      Mean:   2.477           Expected Mean:   2.500   Standard Dev.:  1.101
  Variance:   1.213       Expected Variance:   1.250

      Seed:    .681311976483        Trails:   5.00              Prob:    .90
      Mean:   4.510           Expected Mean:   4.500   Standard Dev.:    .667
  Variance:    .444       Expected Variance:    .450

      Seed:    .983372222047        Trails:  16.00              Prob:    .10
      Mean:   1.576           Expected Mean:   1.600   Standard Dev.:  1.225
  Variance:   1.502       Expected Variance:   1.440
```

```
      Seed:    .016038742609        Trails:  16.00                  Prob:    .50
      Mean:   7.994          Expected Mean:   8.000     Standard Dev.:  2.013
  Variance:   4.052      Expected Variance:   4.000

      Seed:    .468582534523        Trails:  16.00                  Prob:    .90
      Mean:  14.390          Expected Mean:  14.400     Standard Dev.:  1.226
  Variance:   1.503      Expected Variance:   1.440
```

```
      Seed:    .897911534893        Trails:  30.00                  Prob:    .10
      Mean:   2.949          Expected Mean:   3.000     Standard Dev.:  1.597
  Variance:   2.549      Expected Variance:   2.700

      Seed:    .143600845145        Trails:  30.00                  Prob:    .50
      Mean:  15.087          Expected Mean:  15.000     Standard Dev.:  2.792
  Variance:   7.797      Expected Variance:   7.500

      Seed:    .768310767024        Trails:  30.00                  Prob:    .90
      Mean:  26.943          Expected Mean:  27.000     Standard Dev.:  1.641
  Variance:   2.694      Expected Variance:   2.700
```

At this point, you may select a particular data set which you can have printed out or saved on a mass storage device. You will be required to enter the following values: the size of the data set, the starting seed, the number of independent trials and the probability. For want of a better seed, PI is an excellent choice!

BINOMIAL DEVIATES:

Seed: .017453292520   # OF Trials: 10   Prob: .8000

I	X(I)	X(I+1)	X(I+2)	X(I+3)	X(I+4)
1	9.000000	8.000000	9.000000	8.000000	6.000000
6	8.000000	8.000000	8.000000	7.000000	6.000000
11	7.000000	7.000000	10.000000	10.000000	8.000000
16	8.000000	8.000000	10.000000	7.000000	9.000000
21	9.000000	7.000000	8.000000	9.000000	10.000000

(RCHISQ)
Random Numbers From a Chi-square Distribution

(RCHISQ)
Random Numbers From a Chi-square Distribution

Description

Given the number of degrees of freedom and the number of deviates desired, this subprogram generates a set of random numbers with the Chi-square distribution.

File Name

"RCHISQ"

Calling Syntax

CALL Random_chi_sq(N,V,X(*))

Input Parameters

N	number of deviates desired.
V	degrees of freedom.

Output Parameters

X(*)	array of dimension (1:N) containing the N deviates.

Algorithm

This utility generates random deviates for the Chi-square distribution with v degrees of freedom.

For each deviate, if $v=2*k$, where k is an integer

set $x=2*(y1+y2+\ldots+yk)$ where the y's are independent random variables with the exponential distribution, each with mean=1.

If $v=2*k+1$,

set $x=2*(y1+y2+\ldots+yk)+z\wedge 2$ where the y's are as before, and z is a random variable independent of the y's, with the normal distribution (mean=0, standard deviation=1).

Reference

1. Knuth, Donald E., The Art of Computer Programming, Volume 2 Seminumerical Algorithms. Reading, Mass: Addison-Wesley, 1969, p. 115.

Instructions

1. Insert the RANDOM NUMBER cartridge with the machine turned on.
2. a. Type: LOAD "RCHISQ",10
   b. Press: EXECUTE
3. The title "RANDOM CHI-SQUARE DEVIATES" is printed along with the options available to you in the program.
4. When "ENTER YOUR CHOICE. [EITHER 1 OR 2]" is displayed:

   a. Enter 1 if you want to directly generate a set of deviates.

   b. Press: CONT

   c. Go to 8.

   or

   a. Enter 2 if you would like to check through some randomly generated examples.

   b. Press: CONT

   c. Go to 5.

5. Default values are supplied for the size of the sets of deviates, and the Chi-square parameter.

   a. If the default values are satisfactory, simply press: CONT

   or

   a. Change the values as desired.

   b. Press: CONT

6. Three sets of deviates are produced for each sized set. The starting seed as well as the mean, variance and standard deviation of each data set are printed.
7. When "WOULD YOU LIKE TO CONSIDER A PARTICULAR DATA SET? (Y/N)" is displayed:

   a. Enter Y if you would like to generate a particular set to be printed out or saved on a mass storage device.

   b. Press: CONT

   c. Go to 8.

   or

   a. Enter N if no particular set is desired.

   b. Press: CONT

   c. At this point, the program is terminated.

8. When "ENTER VALUES FOR THE SIZE OF THE SET, SEED, CHI-SQUARE PARAMETER. E.G., 10,PI,3" is displayed:

   a. Enter values for the size of the set, the starting seed, and the Chi-square parameter.

   b. Press: CONT

9. When "WOULD YOU LIKE A PRINTOUT OF THE DATA? (Y/N)" is displayed:

   a. Enter Y if a printout is desired.

   b. Press: CONT

   c. Go to 10.

   or

   a. Enter N if a printout is not desired.

   b. Press: CONT

   c. Go to 12.

10. When "ENTER THE SELECT CODE OF THE PRINTER" is displayed:

    a. Enter the select code of the printer.

    b. Press: CONT

11. When "ENTER THE BUS ADDRESS OF THE PRINTER" is displayed:

    a. Enter the bus address of the printer.

    b. Press: CONT

    c. The data set is then printed out on the appropriate device.

12. When "WOULD YOU LIKE TO SAVE THE DATA SET? (Y/N)" is displayed:

    a. Enter Y if you would like it saved.

    b. Press: CONT

    c. Go to 13.

    or

    a. Enter N if you would not like it saved.

    b. Press: CONT

    c. The program is terminated at this point.

13. When "ENTER FILE NAME. FOR EXAMPLE: File:T14 OR DATA:F8" is displayed:

    a. Enter the desired file name.

    b. Press: CONT

    c. The data set is saved on your mass storage device as a vector and the program ends.

```
                    RANDOM CHI-SQUARE DEVIATES

   This program generates sets of Chi-square (V) random deviates.  You may
use the program in two ways:

     1. Directly generate a set of deviates to be printed or saved on a mass
        storage device.

     2. Check through some randomly generated tests in order to get a feel for
        the quality of the deviates produced.  You would then have the option
        to create your own data set.


The program is set up using the following default values:

   1. Three sets of size 50 are produced in turn for each Chi-square
      parameter.
   2. Values for V, the Chi-square parameter, are set in turn at 1, 2, 4
   3. The mean, variance and standard deviation are then printed for each set.

   Default values may be changed from the keyboard as they come up.

# OF RANDOM DEVIATES: 1000
DEGREES OF FREEDOM: 3, 5, 8


CHI-SQUARE PARAMETER:  3

   Seed:     .246190093248
   Mean:    2.993           Variance:     5.467           Standard Dev.:    2.338

   Seed:     .045868421511
   Mean:    2.898           Variance:     6.585           Standard Dev.:    2.566

   Seed:     .575342490784
   Mean:    2.952           Variance:     5.779           Standard Dev.:    2.404


CHI-SQUARE PARAMETER:  5

   Seed:     .863034748332
   Mean:    5.134           Variance:    10.858           Standard Dev.:    3.295

   Seed:     .812223346477
   Mean:    5.051           Variance:     9.682           Standard Dev.:    3.112
```

Seed: .079834386208
Mean: 4.892 Variance: 9.276 Standard Dev.: 3.046

CHI-SQUARE PARAMETER: 8

Seed: .140718800597
Mean: 9.189 Variance: 16.700 Standard Dev.: 4.087

Seed: .344511301952
Mean: 7.873 Variance: 15.289 Standard Dev.: 3.910

Seed: .734004941727
Mean: 8.062 Variance: 16.832 Standard Dev.: 4.103

At this point, you may select a particular data set which you can have printed out or saved on a mass storage device. You will be required to enter the following values: the size of the data set, the starting seed, and the chi-square parameter. For want of a better seed, PI is an excellent choice!

CHI-SQUARE DEVIATES:

Seed: .017453292520 V: 3.0000

I	X(I)	X(I+1)	X(I+2)	X(I+3)	X(I+4)
1	6.937335	1.327848	3.118890	5.009005	2.398437
6	2.617949	1.911048	1.933804	1.571841	8.919987
11	.483659	1.500412	.783231	.238996	4.006474
16	.804631	7.652400	4.543294	1.966788	2.652313
21	2.020308	.794752	2.996792	.468676	2.835952

(REXPON)
Random Numbers From an Exponential Distribution

(REXPON)
Random Numbers From an Exponential Distribution

Description

Given a mean, which you supply, this subprogram generates a set of exponential deviates.

File Name

"REXPON"

Calling Syntax

CALL Random_expon (N,Mu,X(*))

Input Parameters

N	number of deviates desired.
Mu	mean of the distribution.

Output Parameters

X(*)	array of dimension (1:N) containing the N deviates.

Algorithm

This routine uses the random minimization method (due to George Marsaglia) to compute an exponentially distributed variable without using the logarithm subroutine. Although this routine takes slightly more space, it is much faster than the traditional algorithm.

Reference

1. Knuth, Donald E., The Art of Computer Programming, Volume 2 Seminumerical Algorithms. Reading, Mass.: Addison-Wesley, 1969, p. 114.

Instructions

1. Insert the RANDOM NUMBER cartridge with the machine turned on.
2. a. Type: LOAD "REXPON",10
   b. Press: EXECUTE
3. The title "RANDOM EXPONENTIAL DEVIATES" is printed along with the options available to you in the program.

4. When "ENTER YOUR CHOICE. [EITHER 1 OR 2]" is displayed:

   a. Enter 1 if you want to directly generate a set of deviates.

   b. Press: CONT

   c. Go to 8.

   or

   a. Enter 2 if you would like to check through some randomly generated examples.

   b. Press: CONT

   c. Go to 5.

5. Default values are supplied for the size of the sets of deviates, and the means.

   a. If the default values are satisfactory, simply press: CONT

   or

   a. Change the values as desired.

   b. Press: CONT

6. Three sets of deviates are produced for each sized set. The starting seed as well as the mean will be printed. The corresponding Kolmogorov-Smirnov statistics are calculated for each set.

7. When "WOULD YOU LIKE TO CONSIDER A PARTICULAR DATA SET? (Y/N)" is displayed:

   a. Enter Y if you would like to generate a particular set to be printed out or saved on a mass storage device.

   b. Press: CONT

   c. Go to 8.

   or

   a. Enter N is no particular set is desired.

   b. Press: CONT

   c. At this point, the program is terminated.

8. When "ENTER VALUES FOR THE SIZE OF THE SET, SEED, MEAN. E.G.,100,PI,0.5" is displayed:

   a. Enter values for the size of the set, the starting seed, and the mean.

   b. Press: CONT

9. When "WOULD YOU LIKE A PRINTOUT OF THE DATA? (Y/N)" is displayed:

   a. Enter Y if a printout is desired.
   b. Press: CONT
   c. Go to 10.

   or

   a. Enter N if a printout is not desired.
   b. Press: CONT
   c. Go to 12.

10. When "ENTER THE SELECT CODE OF THE PRINTER" is displayed:

    a. Enter the select code of the printer.
    b. Press: CONT

11. When "ENTER THE BUS ADDRESS OF THE PRINTER" is displayed:

    a. Enter the bus address of the printer.
    b. Press: CONT
    c. The data set is then printed out on the appropriate printer.

12. When "WOULD YOU LIKE TO SAVE THE DATA SET? (Y/N)" is displayed:

    a. Enter Y if you would like it saved.
    b. Press: CONT
    c. Go to 13.

    or

    a. Enter N if you would not like it saved.
    b. Press: CONT
    c. The program is terminated at this point.

13. When "ENTER FILE NAME. FOR EXAMPLE: File:T14 OR DATA:F8" is displayed:

    a. Enter the desired file name.
    b. Press: CONT
    c. The data set is saved on your mass storage device as a vector and the program is terminated.

RANDOM EXPONENTIAL DEVIATES

This program generates sets of exponential random deviates. You may use the program in two ways:

1. Directly generate a set of deviates to be printed or saved on a mass storage device.

2. Check through some randomly generated tests in order to get a feel for the quality of the deviates produced. You would then have the option to create your own data set.

This program generates sets of exponential random deviates. It also compares the resulting data with the theoretical expectations using the Kolmogorov-Smirnov test.

The program is set up using the following default values:

1. 0.5, 1.0, 2.5, and 5.0 are selected in turn as the mean.
2. For each parameter, 3 sets of 100 deviates are calculated.
3. The resulting positive and negative K-S statistics are then printed.

Default values may be changed from the keyboard as they come up.

```
# OF DEVIATES IN EACH SET: 1000
MEANS:  0.5, 1.0, 2.5, 5.0

Mean:    .5
      Seed: .723190093254     Knp:     .840     Knn:     .343
      Seed: .202868427612     Knp:     .602     Knn:     .602
      Seed: .612347621784     Knp:     .973     Knn:     .349


Mean:   1.0
      Seed: .984349919381     Knp:     .917     Knn:     .470
      Seed: .838282198047     Knp:     .625     Knn:     .872
      Seed: .995328558683     Knp:     .342     Knn:     .882


Mean:   2.5
      Seed: .071317852203     Knp:     .589     Knn:     .089
      Seed: .978313702577     Knp:     .580     Knn:     .501
      Seed: .761823866397     Knp:     .799     Knn:     .568


Mean:   5.0
      Seed: .693871639521     Knp:     .407     Knn:     .739
      Seed: .546048836977     Knp:    1.075     Knn:     .252
      Seed: .227071896716     Knp:     .628     Knn:     .500
```

At this point, you may select a particular data set which you can have printed out or saved on a mass storage device. You will be required to enter the following values: the size of the data set, the starting seed, and the mean. For want of a better seed, PI is an excellent choice.

EXPONENTIAL DEVIATES:

Seed: .017453292520   Mean: .5000

I	X(I)	X(I+1)	X(I+2)	X(I+3)	X(I+4)
1	1.046715	.898935	.014525	.240158	1.377689
6	.074588	.371152	.096440	1.170035	.715012
11	.237314	.640684	1.233808	.474077	.554652
16	.477486	.426282	.173493	2.229481	.120429
21	.168504	.104212	.010864	.990982	.036880

(RF)
Random Numbers Generated From an F-Distribution

(RF)
Random Numbers Generated From an F-Distribution

Description

Given an F-distribution (variance-ratio distribution) with V1 and V2 degrees of freedom, respectively, this subprogram generates a set of corresponding random deviates.

File Name

"RF"

Calling Syntax

CALL Random_f (N,V1,V2,X(*))

Input Parameters

N	number of deviates desired.
V1, V2	degrees of freedom on the F-distribution.

Output Parameters

X(*)	array of dimension (1:N) containing the N random numbers.

Reference

1. Knuth, Donald E., The Art of Computer Programming, Volume 2 Seminumerical Algorithms. Reading, Mass.: Addison-Wesley, 1969, p. 116.

Instructions

1. Insert the RANDOM NUMBER cartridge with the machine turned on.
2. a. Type: LOAD "RF",10
   b. Press: EXECUTE
3. The title "RANDOM F DEVIATES" is printed along with the options available to you in the program.

4. When "ENTER YOUR CHOICE. [EITHER 1 OR 2]" is displayed:

   a. Enter 1 if you want to directly generate a set of deviates.
   b. Press: CONT
   c. Go to 8.

   or

   a. Enter 2 if you would like to check through some randomly generated examples.
   b. Press: CONT
   c. Go to 5.

5. Default values are supplied for the size of the sets of deviates, and the F parameters.

   a. If the default values are satisfactory, simply press: CONT

   or

   a. Change the values as desired.
   b. Press: CONT

6. A set of deviates is produced for each pair of parameters. The starting seed, mean, and variance are printed as well as the expected mean and variance.
7. When "WOULD YOU LIKE TO CONSIDER A PARTICULAR DATA SET? (Y/N)" is displayed:

   a. Enter Y if you would like to generate a particular set to be printed out or saved on a mass storage device.
   b. Press: CONT
   c. Go to 8.

   or

   a. Enter N if no particular set is desired.
   b. Press: CONT
   c. At this point, the program is terminated.

8. When "ENTER VALUES FOR THE SIZE OF THE SET, SEED, V1, V2.E.G., 10, PI,5,7" is displayed:

   a. Enter values for the size of the set, the starting seed, and the F parameters.
   b. Press: CONT

9. When "WOULD YOU LIKE A PRINTOUT OF THE DATA? (Y/N)" is displayed:

   a. Enter Y if a printout is desired.
   b. Press: CONT
   c. Go to 10.

   or

   a. Enter N if a printout is not desired.
   b. Press: CONT
   c. Go to 12.

10. When "ENTER THE SELECT CODE OF THE PRINTER" is displayed:

    a. Enter the select code of the printer.
    b. Press: CONT

11. When "ENTER THE BUS ADDRESS OF THE PRINTER" is displayed:

    a. Enter the bus address of the printer.
    b. Press: CONT
    c. The data set is then printed out on the appropriate device.

12. When "WOULD YOU LIKE TO SAVE THE DATA SET? (Y/N)" is displayed:

    a. Enter Y if you would like it saved.
    b. Press: CONT
    c. Go to 13.

    or

    a. Enter N if you would not like it saved.
    b. Press: CONT
    c. The program is terminated at this point.

13. When "ENTER FILE NAME. FOR EXAMPLE: File:T14 OR DATA:F8" is displayed:

    a. Enter the desired file name.
    b. Press: CONT
    c. The data set is saved on your mass storage device as a vector and the program ends.

RANDOM F DEVIATES

This program generates sets of F(V1,V2) random deviates. You may use the program in two ways:

1. Directly generate a set of deviates to be printed or saved on a mass storage device.

2. Check through some randomly generated tests in order to get a feel for the quality of the deviates produced. You would then have the option to create your own data set.

This program generates sets of F(V1,V2) random deviates. It also compares the resulting data with the theoretical expectations. In particular, given degrees of freedom V1 and V2, the mean and variance of each set of F random numbers is calculated.

The expected value of the mean is:

V2/(V2-2) for V2>2.

The expected value of the variance is:

2*V2^2*(V1+V2-2)/(V1*(V2-4)*(V2-2)^2) for V2>4.

The program is set up using the following default values:

1. 100 deviates will be generated for each set of F parameters.
2. Values for V1 and V2, the F parameters, are set at 5, 10, 50.
3. Results printed are:
   - mean, expected mean, and standard deviation for each set.
   - variance and expected variance for each set.

Default values may be changed from the keyboard as they come up.

```
# OF RANDOM DEVIATES: 1000
DEGREES OF FREEDOM (V1): 5, 10, 50
DEGREES OF FREEDOM (V2): 5, 10, 50


Number:  1000

      Seed:   .621900932048            V1:   5.00                     V2:   5.00
      Mean:   1.762         Expected Mean:   1.667   Standard Dev.:   2.463
  Variance:   6.067     Expected Variance:   8.889

      Seed:   .018683852607            V1:   5.00                     V2:  10.00
      Mean:   1.337         Expected Mean:   1.250   Standard Dev.:   1.253
  Variance:   1.570     Expected Variance:   1.354

      Seed:   .713120642531            V1:   5.00                     V2:  50.00
      Mean:   1.073         Expected Mean:   1.042   Standard Dev.:    .754
  Variance:    .568     Expected Variance:    .500
```

```
     Seed:    .733955768681          V1:  10.00                  V2:  5.00
     Mean:   1.565         Expected Mean:   1.667    Standard Dev.:  1.841
 Variance:   3.390     Expected Variance:   7.222

     Seed:    .256801459317          V1:  10.00                  V2: 10.00
     Mean:   1.269         Expected Mean:   1.250    Standard Dev.:   .956
 Variance:    .914     Expected Variance:    .938

     Seed:    .970027285542          V1:  10.00                  V2: 50.00



     Mean:   1.037         Expected Mean:   1.042    Standard Dev.:   .547
 Variance:    .299     Expected Variance:    .274

     Seed:    .792947140391          V1:  50.00                  V2:  5.00
     Mean:   1.755         Expected Mean:   1.667    Standard Dev.:  2.788
 Variance:   7.775     Expected Variance:   5.889

     Seed:    .868545067767          V1:  50.00                  V2: 10.00
     Mean:   1.258         Expected Mean:   1.250    Standard Dev.:   .762
 Variance:    .581     Expected Variance:    .604

     Seed:    .446401990806          V1:  50.00                  V2: 50.00
     Mean:   1.028         Expected Mean:   1.042    Standard Dev.:   .302
 Variance:    .091     Expected Variance:    .092
```

At this point, you may select a particular data set which you can have printed out or saved on a mass storage device. You will be required to enter the following values: the size of the data set, the starting seed, and the two F parameters. For want of a better seed, PI is an excellent choice!

F DEVIATES:

Seed: .017453292520   V1:   5.0000   V2:   7.0000

I	X(I)	X(I+1)	X(I+2)	X(I+3)	X(I+4)
1	1.926214	1.334536	1.448058	.970933	1.029440
6	.414127	.206951	.976291	2.265742	1.718479
11	.094033	.562395	1.693379	.500013	1.372930
16	1.372621	7.519611	.966455	.352944	1.147062
21	.798963	1.640397	.619726	.486223	.839288

(RGAMM1) Random Integers Generated From a Gamma (Alpha) Distribution

(RGAMM1) Random Integers Generated From a Gamma (Alpha) Distribution

Description

This subprogram generates a set of Gamma (Alpha) deviates.

File Name

"RGAMM1"

Calling Syntax

CALL Random_gamma1 (N,Alpha,X(*))

Input Parameters

N	number of random numbers desired.
Alpha	Gamma parameter.

Output Parameters

X(*)	array of dimension (1:N) containing numbers randomly generated with the given Gamma distribution.

Instructions

1. Insert the RANDOM NUMBER cartridge with the machine turned on.
2. a. Type: LOAD "RGAMM1",10
   b. Press: EXECUTE
3. The title "RANDOM GAMMA (Alpha) DEVIATES" is printed along with options available to you in the program.
4. When "ENTER YOUR CHOICE. [EITHER 1 OR 2]" is displayed:

   a. Enter 1 if you want to directly generate a set of deviates.

   b. Press: CONT

   c. Go to 8.

   or

   a. Enter 2 if you would like to check through some randomly generated examples.

   b. Press: CONT

   c. Go to 5.

5. Default values are supplied for the size of the set of deviates, and the probabilities.

   a. If the default values are satisfactory, simply press: CONT

   or

   a. Change the values as desired.

   b. Press: CONT

6. Three sets of deviates with different starting seeds are produced for each parameter. After each data set is generated, the starting seed, the parameter, and the mean and variance of each set is printed.

7. When "WOULD YOU LIKE TO CONSIDER A PARTICULAR DATA SET? (Y/N)" is displayed:

   a. Enter Y if you would like to generate a particular set to be printed out or saved on a mass storage device.

   b. Press: CONT

   or

   a. Enter N if no particular set is desired.

   b. Press: CONT

   c. At this point, the program is terminated.

8. When "ENTER VALUES FOR THE SIZE OF THE SET, SEED, GAMMA PARAMETER. E.G., 100,PI,3.5" is displayed:

   a. Enter values for the size of the set, the starting seed, and the Gamma parameter.

   b. Press: CONT

9. After the data set has been created, the prompt: "WOULD YOU LIKE A PRINTOUT OF THE DATA? (Y/N)" is displayed:

   a. Enter Y if a printout is desired.

   b. Press: CONT

   c. Go to 10.

   or

   a. Enter N if a printout is not desired.

   b. Press: CONT

   c. Go to 12.

10. When "ENTER THE SELECT CODE OF THE PRINTER." is displayed:

    a. Enter the select code of the printer.

    b. Press: CONT

Alpha: 10.25

Seed: .697946620926
Mean: 10.224 Variance: 10.071 Standard Dev.: 3.173

Seed: .973108200152
Mean: 9.834 Variance: 12.735 Standard Dev.: 3.569

Seed: .383996327637
Mean: 10.559 Variance: 11.641 Standard Dev.: 3.412

At this point, you may select a particular data set which you can have printed out or stored on a mass storage device. You will be required to enter the following values: the size of the data set, the starting seed, and the Gamma parameter. For want of a better seed, PI is an excellent choice!

GAMMA DEVIATES:

Seed: .017453292520 Alpha: 3.5000

I	X(I)	X(I+1)	X(I+2)	X(I+3)	X(I+4)
1	4.229690	1.309675	4.406097	3.134771	5.225892
6	4.719702	.873601	3.696969	2.242268	4.142567
11	4.628855	4.743018	5.467311	3.777862	3.119722
16	2.274009	2.568017	6.147779	.325210	4.059675
21	2.393629	2.748339	1.689142	6.686583	4.246621

(RGAMM2)
Random Numbers Generated From a Gamma (A,B) Distribution

(RGAMM2)
Random Numbers Generated From a Gamma (A,B) Distribution

Description

This subprogram generates a set of Gamma (A,B) random deviates.

File Name

"RGAMM2"

Calling Syntax

CALL Random_gamma2 (N,A,B,X(*))

Input Parameters

N	number of random deviates desired.
A,B	Gamma parameters.

Output Parameters

X(*)	array of dimension (1:N) containing deviates randomly generated with the Gamma distribution.

Algorithm

1. Given Gamma parameters A and B, generate B independent exponential deviates with mean=A.
2. The corresponding Gamma deviate is equal to the sum of the B exponential deviates.

Instructions

1. Insert the RANDOM NUMBER cartridge with the machine turned on.
2. a. Type: LOAD "RGAMM2",10
   b. Press: EXECUTE
3. The title "RANDOM GAMMA DEVIATES" is printed along with options available to you in the program.

4. When "ENTER YOUR CHOICE. [EITHER 1 OR 2]" is displayed:

   a. Enter 1 if you want to directly generate a set of deviates.
   b. Press: CONT
   c. Go to 8.

   or

   a. Enter 2 if you would like to check through some randomly generated examples.
   b. Press: CONT
   c. Go to 5.

5. Default values are supplied for the size of the sets of deviates, and the parameters.

   a. If the default values are satisfactory, simply press: CONT

   or

   a. Change the values as desired.
   b. Press: CONT

6. One set of deviates is produced with a different starting seed for each set of parameters. After each data set is generated, the starting seed, the parameters, and the mean and variance of the set are printed as well as the expected mean and variance.

7. When "WOULD YOU LIKE TO CONSIDER A PARTICULAR DATA SET? (Y/N)" is displayed:

   a. Enter Y if you would like to generate a particular set to be printed out or saved on a mass storage device.
   b. Press: CONT

   or

   a. Enter N if no particular set is desired.
   b. Press: CONT
   c. At this point, the program is terminated.

8. When "ENTER VALUES FOR THE SIZE OF THE SET, SEED, A,B. E.G., 100,PI,3.5" is displayed:

   a. Enter values for the size of the set, the starting seed, and the appropriate parameters.
   b. Press: CONT

9. After the data set has been created, the prompt: "WOULD YOU LIKE A PRINTOUT OF THE DATA? (Y/N)" is displayed:

a. Enter Y if a printout is desired.

b. Press: CONT

c. Go to 10.

or

a. Enter N if a printout is not desired.

b. Press: CONT

c. Go to 12.

10. When "ENTER THE SELECT CODE OF THE PRINTER." is displayed:

    a. Enter the select code of the printer.

    b. Press: CONT

11. When "ENTER THE BUS ADDRESS OF THE PRINTER." is displayed:

    a. Enter the bus address of the printer.

    b. Press: CONT

12. When "WOULD YOU LIKE TO SAVE YOUR DATA SET? (Y/N)" is displayed:

    a. Enter Y if you would like it saved.

    b. Press: CONT

    c. Go to 13.

    or

    a. Enter N if you would not like it saved.

    b. Press: CONT

    c. At this point, the program terminates.

13. When "ENTER FILE NAME. FOR EXAMPLE, File:T14 OR DATA:F8" is displayed.

    a. Enter the desired file name.

    b. Press: CONT

    c. The data set is saved on your mass storage device as a vector and the program ends.

RANDOM GAMMA DEVIATES

This program generates sets of Gamma (A,B) random deviates. You may use the program in two ways:

1. Directly generate a set of deviates to be printed or saved on a mass storage device.

2. Check through some randomly generated tests in order to get a feel for the quality of the deviates produced. You would then have the option to create your own data set.

This program generates sets of Gamma (A,B) random deviates. It also compares the resulting data with the theoretical expectations. In particular, given the parameters A and B, the mean and variance of each set of Gamma deviates is calculated.

The expected value of the mean is: A*B.
The expected value of the variance is: A*A*B.

The program is set up using the following default values:

1. 50 deviates will be generated for each set of Gamma parameters.
2. Values for A are set at .2, and 1.
3. Values for B are set at 2, and 5.
4. Results printed are:
   - mean, expected mean, and standard deviation for each set.
   - variance and expected variance for each set.

Default values may be changed from the keyboard as they come up.

```
# OF RANDOM DEVIATES: 1000
A PARAMETERS: .2, 1
B PARAMETERS: 2, 5


Number:   1000

     Seed:   .882190093254            A:     .20                     B:   2.00
     Mean:   .401          Expected Mean:    .400     Standard Dev.:     .283
 Variance:   .080      Expected Variance:    .080

     Seed:   .921868427612            A:     .20                     B:   5.00
     Mean:  1.012          Expected Mean:   1.000     Standard Dev.:     .457
 Variance:   .209      Expected Variance:    .200

     Seed:   .291347620384            A:    1.00                     B:   2.00
     Mean:  2.000          Expected Mean:   2.000     Standard Dev.:    1.404
 Variance:  1.970      Expected Variance:   2.000
```

Seed: .023348743108 A. 1.00 B: 5.00
Mean: 5.100 Expected Mean: 5.000 Standard Dev.: 2.361
Variance: 5.572 Expected Variance: 5.000

At this point, you may select a particular data set which you can have printed out or saved on a mass storage device. You will be required to enter the following values: the size of the data set, the starting seed, and the values of the parameters A and B. For want of a better seed, PI/180 is an excellent choice!

GAMMA DEVIATES:

Seed: .017453292520 A: .2000 B: 8.0000

I	X(I)	X(I+1)	X(I+2)	X(I+3)	X(I+4)
1	1.648080	2.201227	1.689699	1.694490	1.143761
6	1.996747	1.423744	1.531812	1.056391	1.397026
11	1.799022	1.344000	1.601870	1.315438	1.134806
16	1.962800	1.509895	1.679329	2.984781	1.419627
21	2.039519	1.797392	1.764438	2.161114	1.718534

(RGEOM)
Random Integers Generated From a Geometric Distribution

(RGEOM)
Random Integers Generated From a Geometric Distribution

Description

Given that a certain event occurs with probability P, this subprogram generates N random integers with the appropriate Geometric distribution; that is, each random integer represents the number of individual trials needed until the given event first occurs (or between occurrences of the event).

File Name

"RGEOM"

Calling Syntax

Call Random_geom (N,P,Integer(*))

Input Parameters

N	number of random integers desired.
P	probability of a given event occurring.

Output Parameters

Integer(*)	array of dimension (1:N) containing integers randomly generated for the number of independent trials needed until the given event occurs.

Algorithm

The probability of the event first occurring on the Rth trial is $P*(1-P)\wedge(R-1)$.

A convenient way to generate a variable with this distribution when P is small is to set R = the least integer function of $[\ln(U)/\ln(1-P)]$ where U is a uniformly generated random number.

Reference

1. Knuth, Donald E., The Art of Computer Programming, Volume 2 Seminumerical Algorithms, Reading, Mass.: Addison-Wesley, p. 116.

Instructions

1. Insert the RANDOM NUMBER cartridge with the machine turned on.
2. a. Type: LOAD "RGEOM",10
   b. Press: EXECUTE
3. The title "RANDOM GEOMETRIC DEVIATES" is printed along with the options available to you in the program.

4. When "ENTER YOUR CHOICE. [EITHER 1 or 2]" is displayed:

   a. Enter 1 if you want to directly generate a set of deviates.
   b. Press: CONT
   c. Go to 8.

   or

   a. Enter 2 if you would like to check through some randomly generated examples.
   b. Press: CONT
   c. Go to 5.

5. Default values are supplied for the size of the set of deviates, and the probabilities.

   a. If the default values are satisfactory, simply press: CONT

   or

   a. Change the values as desired.
   b. Press: CONT

6. Three sets of deviates are produced for each sized set. The starting seed, as well as the probability, is printed. The mean and variance of each data set are also printed as well as the expected mean and variance.
7. When "WOULD YOU LIKE TO CONSIDER A PARTICULAR DATA SET? (Y/N)" is displayed:

   a. Enter Y if you would like to generate a particular set to be printed out or saved on a mass stoage device.
   b. Press: CONT

   or

   a. Enter N if no particular set is desired.
   b. Press: CONT
   c. At this point, the program is terminated.

8. When "ENTER VALUES FOR THE SIZE OF THE SET, SEED, PROBABILITY. E.G., 100, PI,.8" is displayed:

   a. Enter values for the size of the set, the starting seed, and the probability.
   b. Press: CONT

9. After the data set has been created, the prompt: "WOULD YOU LIKE A PRINTOUT OF THE DATA? (Y/N)" is displayed:

   a. Enter Y if a printout is desired.

   b. Press: CONT

   c. Go to 10.

   or

   a. Enter N if a printout is not desired.

   b. Press: CONT

   c. Go to 12.

10. When "ENTER THE SELECT CODE OF THE PRINTER." is displayed:

    a. Enter the select code of the printer.

    b. Press: CONT

11. When "ENTER THE BUS ADDRESS OF THE PRINTER." is displayed:

    a. Enter the bus address of the printer.

    b. Press: CONT

12. When "WOULD YOU LIKE TO SAVE THE DATA SET? (Y/N)" is displayed:

    a. Enter Y if you would like it saved.

    b. Press: CONT

    c. Go to 13.

    or

    a. Enter N if you would not like it saved.

    b. Press: CONT

    c. At this point, the program terminates.

13. When "ENTER FILE NAME. FOR EXAMPLE, File:T14 OR DATA:F8" is displayed:

    a. Enter the desired file name.

    b. Press: CONT

    c. The data set is saved on your mass storage device as a vector and the program ends.

RANDOM GEOMETRIC DEVIATES

This program generates sets of Gemoetric (P) random deviates. You may use the program in two ways:

1. Directly generate a set of deviates to be printed or saved on a mass storage device.

2. Check through some randomly generated tests in order to get a feel for the quality of the deviates produced. You would then have the option to create your own data set.

This program generates sets of Geometric (P) random deviates. It also compares the resulting data with the theoretical expectations. In particular, given a probability P, the mean and variance of each set of Geometric random numbers is calculated.

The expected value of the mean is: 1/P.
The expected value of the variance is: (1-P)/(P*P).

The program is set up using the following default values:

1. 100 deviates will be generated for each Geometric probability.
2. Values for the probability are set at 0.10, 0.50, and 0.75.
3. Results printed are:
   - mean, expected mean, and standard deviation for each set.
   - variance and expected variance for each set.

Default values may be changed from the keyboard as they come up.

```
# OF RANDOM DEVIATES: 1000
PROBABILITIES: 0.10, 0.50, 0.75


Prob.: .100

        Seed:    .982190093254
        Mean:   9.574        Expected Mean:  10.000     Standard Dev.:  9.172
    Variance:  84.119    Expected Variance:  90.000

        Seed:    .021868427601
        Mean:  10.288        Expected Mean:  10.000     Standard Dev.:  9.885
    Variance:  97.717    Expected Variance:  90.000

        Seed:    .391347612684
        Mean:  10.421        Expected Mean:  10.000     Standard Dev.: 10.303
    Variance: 106.148    Expected Variance:  90.000
```

```
Prob.: .500

      Seed:    .123342266280
      Mean:   1.967          Expected Mean:    2.000     Standard Dev.:  1.437
  Variance:   2.066      Expected Variance:    2.000

      Seed:    .730845941525
      Mean:   2.011          Expected Mean:    2.000     Standard Dev.:  1.374
  Variance:   1.887      Expected Variance:    2.000

      Seed:    .641436821832
      Mean:   1.980          Expected Mean:    2.000     Standard Dev.:  1.380



  Variance:   1.904      Expected Variance:    2.000


Prob.: .750

      Seed:    .448367159967
      Mean:   1.325          Expected Mean:    1.333     Standard Dev.:   .632
  Variance:    .400      Expected Variance:     .444

      Seed:    .076781531006
      Mean:   1.326          Expected Mean:    1.333     Standard Dev.:   .650
  Variance:    .422      Expected Variance:     .444

      Seed:    .573267576264
      Mean:   1.329          Expected Mean:    1.333     Standard Dev.:   .644
  Variance:    .415      Expected Variance:     .444
```

At this point, you may select a particular data set which you can have printed out or saved on a mass storage device. You will be required to enter the following values: the size of the data set, the starting seed, and the probability. For want of a better seed, PI is an excellent choice!

GEOMETRIC DEVIATES:

Seed: .017453292520   Prob: .8000

I	X(I)	X(I+1)	X(I+2)	X(I+3)	X(I+4)
1	1.000000	2.000000	1.000000	1.000000	1.000000
6	1.000000	1.000000	3.000000	2.000000	1.000000
11	1.000000	2.000000	5.000000	1.000000	1.000000
16	1.000000	2.000000	1.000000	1.000000	2.000000
21	1.000000	1.000000	3.000000	1.000000	2.000000

(RLNORM)
Random Lognormal Deviates

(RLNORM)
Random Lognormal Deviates

Description

This subprogram generates a set of random lognormal deviates with mean=Mu and standard deviation=Sigma.

File Name

"RLNORM"

Calling Syntax

CALL Random_lognorm (N,Mu,Sigma,X(*))

Input Parameters

N	number of deviates desired.
Mu	mean of the distribution.
Sigma	standard deviation of the distribution.

Output Parameters

X(*)	array of dimension(1:N) containing the N lognormal deviates.

Algorithm

1. Let S = log [(Sigma∧2)/(Mu∧2)+1].
2. Let U = log (Mu) − 0.5*S.
3. Generate a normal deviate A, with mean = U and standard deviation = Square Root of(S).
4. Then the lognormal deviate is equal to exp (A).

Reference

1. Reddy, Y.V., "PL/I Process Generators", SIMULETTER, Vol. III, Oct. 1976, p. 27.

Instructions

1. Insert the RANDOM NUMBER cartridge with the machine turned on.
2. a. Type: LOAD "RLNORM",10
   b. Press: EXECUTE
3. The title "RANDOM LOGNORMAL DEVIATES" is printed along with the options available to you in the program.

4. When "ENTER YOUR CHOICE. [EITHER 1 OR 2]" is displayed:

   a. Enter 1 if you want to directly generate a set of deviates.
   b. Press: CONT
   c. Go to 8.

   or

   a. Enter 2 if you would like to check through some randomly generated examples.
   b. Press: CONT
   c. Go to 5.

5. Default values are supplied for the size of the sets of deviates, the means and standard deviations.

   a. If the default values are satisfactory, simply press: CONT

   or

   a. Change the values as desired.
   b. Press: CONT

6. Three sets of deviates are produced for each sized set. The starting seed as well as the mean and standard deviation are printed and can be compared with the user specified values.

7. When "WOULD YOU LIKE TO CONSIDER A PARTICULAR DATA SET? (Y/N)" is displayed:

   a. Enter Y if you would like to generate a particular set to be printed out or saved on a mass storage device.
   b. Press: CONT
   c. Go to 8.

   or

   a. Enter N if no particular set is desired.
   b. Press: CONT
   c. At this point, the program is terminated.

8. When "ENTER VALUES FOR THE SIZE OF THE SET, SEED, MEAN, SD. E.G., 100,PI,5,2.5" is displayed:

   a. Enter values for the size of the set, the starting seed, the mean and standard deviation.
   b. Press: CONT

9. After the data set has been created, the prompt: "WOULD YOU LIKE THE DATA SET STORED ON A MASS STORAGE DEVICE? (Y/N)" will be displayed:

   a. Enter Y if you would like it saved.

   b. Press: CONT

   c. Go to 10.

   or

   a. Enter N if you would not like it saved.

   b. Press: CONT

   c. Go to 11.

10. When "ENTER THE FILE NAME. FOR EXAMPLE: File:T14 OR DATA:F8" is displayed:

    a. Enter the desired file name.

    b. Press: CONT

    c. The data set is saved on your mass storage device as a vector.

11. When "WOULD YOU LIKE A PRINTOUT OF THE DATA? (Y/N)" is displayed:

    a. Enter Y if a printout is desired.

    b. Press: CONT

    c. Go to 12.

    or

    a. Enter N if a printout is not desired.

    b. Press: CONT

    c. The program is terminated at this point.

12. When "ENTER THE SELECT CODE OF THE PRINTER." is displayed:

    a. Enter the select code of the printer.

    b. Press: CONT

13. When "ENTER THE BUS ADDRESS OF THE PRINTER." is displayed:

    a. Enter the bus address of the printer.

    b. Press: CONT

    c. The data set is then printed out on the appropriate printer.

    d. The program is terminated at this point.

RANDOM LOGNORMAL DEVIATES

This program generates sets of Log Normal random deviates with user-defined mean and standard deviation. You may use the program in two ways:

1. Directly generate a set of deviates to be printed or saved on a mass storage device.

2. Check through some randomly generated tests in order to get a feel for the quality of the deviates produced. You would then have the option to create your own data set.

The program is set up using the following default values:

1. Five different sets of means and standard deviations are used: (.5,.5), (2,.5), (.5,2), (10,1), and (1,10).
2. Three tests are performed for each mean and standard deviation using 100 log normal random numbers for each set.
3. For each test, the mean and standard deviation are calculated. These values can then be compared with the expected mean and standard deviation.

Default values may be changed from the keyboard as they come up.

```
# OF DIFFERENT MEANS AND SDs: 5

Mean:     .50      Standard Deviation:     .50
     Seed:     .822190093254       Mean:    .428      Standard Dev.:    .332
     Seed:     .461868427612       Mean:    .568      Standard Dev.:    .524
     Seed:     .431347620384       Mean:    .544      Standard Dev.:    .444

Mean:    2.00      Standard Deviation:     .50
     Seed:     .763348741980       Mean:   1.998      Standard Dev.:    .519
     Seed:     .976292004613       Mean:   1.987      Standard Dev.:    .488
     Seed:     .061575880207       Mean:   2.028      Standard Dev.:    .473

Mean:     .50      Standard Deviation:    2.00
     Seed:     .785315254000       Mean:    .492      Standard Dev.:    .629
     Seed:     .450128614042       Mean:    .498      Standard Dev.:   1.102
     Seed:     .558164408898       Mean:    .349      Standard Dev.:    .684

Mean:   10.00      Standard Deviation:    1.00
     Seed:     .416267382067       Mean:  10.334      Standard Dev.:   1.153
     Seed:     .061288817109       Mean:   9.954      Standard Dev.:    .927
     Seed:     .363895188375       Mean:   9.949      Standard Dev.:    .985

Mean:    1.00      Standard Deviation:   10.00
     Seed:     .035853424106       Mean:    .784      Standard Dev.:   2.425
     Seed:     .152729673092       Mean:    .511      Standard Dev.:    .875
     Seed:     .445655070460       Mean:   1.185      Standard Dev.:   4.566
```

At this point, you may select a particular data set which you can have printed out or saved on a mass storage device. You will be required to enter the following values: the size of the data set, the starting seed, the mean and the standard deviation. For want of a better seed, PI is an excellent choice!

LOGNORMAL DEVIATES:

Seed: .01745329252 0 Mean: 5.0000 Sd: 3.0000

I	X(I)	X(I+1)	X(I+2)	X(I+3)	X(I+4)
1	3.674948	3.048059	6.483291	3.687992	6.351107
6	6.086736	4.367232	3.288814	2.550134	4.180853
11	4.183955	2.589870	3.065009	5.478875	4.807000
16	2.735173	3.100603	9.897996	3.224541	4.471662
21	1.986578	4.558286	2.445821	3.258126	5.840190

(RNEGBI)
Random Numbers Generated From a Negative Binomial Distribution

(RNEGBI)
Random Numbers Generated From a Negative Binomial Distribution

Description

This subprogram generates a set of Negative Binomial random deviates.

File Name

"RNEGBI"

Calling Syntax

CALL Random_neg_bin (N,R,P,X(*))

Input Parameters

N	number of random integers desired.
R	failure value.
P	probability.

Output Parameters

X(*)	array of dimension (1:N) containing integers randomly generated with the Negative Binomial distribution.

Algorithm

1. Given parameters R and P, generate R random geometric deviates with parameter P.
   a. Change the values as desired.
   b. Press: CONT
2. The corresponding Negative Binomial Deviate is equal to the sum of the R geometric deviates.

Reference

1. Wheeler, R. E., "Random Variable Generators", SIMULETTER, Vol. IV, April, 1973, p. 22.

Instructions

1. Insert the RANDOM NUMBER cartridge with the machine turned on.
2. a. Type: LOAD "RNEGBI",10
   b. Press: EXECUTE
3. The title "RANDOM NEGATIVE BINOMIAL DEVIATES" is printed along with the options available to you in the program.

4. When "ENTER YOUR CHOICE. [EITHER 1 OR 2]" is displayed:

   a. Enter 1 if you want to directly generate a set of deviates.
   b. Press: CONT
   c. Go to 8.

   or

   a. Enter 2 if you would like to check through some randomly generated examples.
   b. Press: CONT
   c. Go to 5.

5. Default values are supplied for the size of the sets of deviates and the parameters.

   a. If the default values are satisfactory, simply press: CONT

   or

   a Change the values as desired.
   b. Press: CONT

6. One set of deviates is produced with a different starting seed for each set of parameters. After each data set is generated, the starting seed, the parameters, and the mean and variance of the set are printed as well as the expected mean and variance.

7. When "WOULD YOU LIKE TO CONSIDER A PARTICULAR DATA SET? (Y/N)" is displayed:

   a. Enter Y if you would like to generate a particular set to be printed out or saved on a mass storage device.
   b. Press: CONT

   or

   a. Enter N if no particular set is desired.
   b. Press: CONT
   c. At this point, the program is terminated.

8. When "ENTER VALUES FOR THE SIZE OF THE SET, SEED, R, PROBABILITY. E.G., 100,PI,4,.8" is displayed:

   a. Enter values for the size of the set, the starting seed, and the appropriate parameters.
   b. Press: CONT

9. After the data set has been created, the prompt: "WOULD YOU LIKE A PRINTOUT OF THE DATA? (Y/N)" is displayed:

   a. Enter Y if a printout is desired.

   b. Press: CONT

   c. Go to 10.

   or

   a. Enter N if a printout is not desired.

   b. Press: CONT

   c. Go to 12.

10. When "ENTER THE SELECT CODE OF THE PRINTER." is displayed:

    a. Enter the select code of the printer.

    b. Press: CONT

11. When "ENTER THE BUS ADDRESS OF THE PRINTER." is displayed:

    a. Enter the bus address of the printer.

    b. Press: CONT

12. When "WOULD YOU LIKE TO SAVE YOUR DATA SET? (Y/N)" is displayed:

    a. Enter Y if you would like it saved.

    b. Press: CONT

    c. Go to 13.

    or

    a. Enter N if you would not like it saved.

    b. Press: CONT

    c. At this point, the program terminates.

13. When "ENTER FILE NAME. FOR EXAMPLE, File:T14 OR DATA:F8" is displayed:

    a. Enter the desired file name.

    b. Press: CONT

    c. The data set is saved on your mass storage device as a vector and the program ends.

RANDOM NEGATIVE BINOMIAL DEVIATES

This program generates sets of Negative Binomial (R,P) random deviates. You may use the program in two ways:

1. Directly generate a set of deviates to be printed or saved on a mass storage device.

2. Check through some randomly generated tests in order to get a feel for the quality of the deviates produced. You would then have the option to create your own data set.

This program generates sets of Negative Binomial (R,P) random deviates. It also compares the resulting data with the theoretical expectations. In particular, given a probability P and a failure value R, the mean and variance of each set of deviates, as well as the expected mean and variance is calculated.

The expected value of the mean is: R/P.
The expected value of the variance is: R*(1-P)/(P*P).

The program is set up using the following default values:

1. 100 deviates will be generated for each Negative binomial probability and failure value R.
2. Values for the probability are set at 0.10, 0.50, and 0.75. Values for R are set at 2, 5, and 10.
3. Results printed are:
   - mean, expected mean, and standard deviation for each set.
   - variance and expected variance for each set.

Default values may be changed from the keyboard as they come up.

```
# OF RANDOM DEVIATES: 1000
FAILURE VALUES: 2, 5, 10
PROBABILITIES: 0.10, 0.50, 0.75


Failure:   2      Prob.: .100

        Seed:     .892190093254
        Mean:   20.971          Expected Mean:   20.000      Standard Dev.: 14.010
    Variance: 196.284      Expected Variance: 180.000


Failure:   2      Prob.: .500

        Seed:     .331868427612
        Mean:   4.022           Expected Mean:    4.000      Standard Dev.:  2.020
    Variance:   4.080      Expected Variance:   4.000
```

```
Failure:   2      Prob.: .750

        Seed:     .101347621784
        Mean:    2.682          Expected Mean:    2.667     Standard Dev.:    .929
    Variance:     .864      Expected Variance:     .889

Failure:   5      Prob.: .100

        Seed:     .233349920581



        Mean:  49.398           Expected Mean:  50.000     Standard Dev.: 20.303
    Variance: 412.218       Expected Variance: 450.000

Failure:   5      Prob.: .500

        Seed:     .247283208747
        Mean:    9.982          Expected Mean:  10.000     Standard Dev.:  3.148
    Variance:    9.912      Expected Variance:  10.000

Failure:   5      Prob.: .750

        Seed:     .965178556113
        Mean:    6.657          Expected Mean:   6.667     Standard Dev.:  1.503
    Variance:    2.258      Expected Variance:   2.222

Failure:  10      Prob.: .100

        Seed:     .715165691778
        Mean: 100.759           Expected Mean: 100.000     Standard Dev.: 30.737
    Variance: 944.754       Expected Variance: 900.000

Failure:  10      Prob.: .500

        Seed:     .454346786405
        Mean:  20.071           Expected Mean:  20.000     Standard Dev.:  4.330
    Variance:  18.745       Expected Variance:  20.000

Failure:  10      Prob.: .750

        Seed:     .105647365356
        Mean:  13.309           Expected Mean:  13.333     Standard Dev.:  2.090
    Variance:   4.368       Expected Variance:   4.444
```

At this point, you may select a particular data set which you can have printed out or saved on a mass storage device. You will be required to enter the following values: the size of the data set, the starting seed, the failure value and the probability. For want of a better seed, PI is an excellent choice!

NEGATIVE BINOMIAL DEVIATES:

Seed: .01745329252 Failure: 4 Prob: .8000

I	X(I)	X(I+1)	X(I+2)	X(I+3)	X(I+4)
1	5.000000	6.000000	6.000000	8.000000	6.000000
6	6.000000	6.000000	4.000000	4.000000	4.000000
11	4.000000	5.000000	5.000000	6.000000	5.000000
16	5.000000	4.000000	4.000000	5.000000	6.000000
21	4.000000	6.000000	4.000000	5.000000	4.000000

(RNORM)
Normal Random Deviates With Mean=0 and Standard Deviation=1

(RNORM)
Normal Random Deviates With Mean=0 And Standard Deviation=1

Description

This subprogram calculates an even number of normally distributed variables with mean=0 and standard deviation=1.

File Name

"RNORM"

Calling Syntax

CALL Random_normal (N,X(*))

Input Parameters

N	number of normal deviates desired. N must be even.

Output Parameters

X(*)	array of dimension (1:N) containing the N normal deviates.

Algorithm

This utility generates random deviates for the normal distribution with mean=0 and standard deviation=1. An adapted form of the Polar Method is used. (See Reference 1.)

Special Considerations

1. Due to the nature of the algorithm used, this routine generates an even number of normal deviates. If an odd number is requested, an error message is printed and the routine has to be re-entered again.
2. This method is rather slow, but it has essentially perfect accuracy and takes a minimum of storage space.

Reference

1. Knuth, Donald E., The Art of Computer Programming, Volume 2 Seminumerical Algorithms. Reading, Mass.: Addison-Wesley, 1969, p. 104.

Instructions

1. Insert the RANDOM NUMBER cartridge with the machine turned on.
2. a. Type: LOAD "RNORM",10
   b. Press: EXECUTE
3. The title "RANDOM NORMAL DEVIATES" is printed along with the options available to you in the program.

4. When "ENTER YOUR CHOICE. [EITHER 1 OR 2]" is displayed:

   a. Enter 1 if you want to directly generate a set of deviates.
   b. Press: CONT
   c. Go to 8.

   or

   a. Enter 2 if you would like to check through some randomly generated examples.
   b. Press: CONT
   c. Go to 5.

5. Default values are supplied for the size of the sets of deviates.

   a. If the default values are satisfactory, simply press: CONT

   or

   a. Change the values as desired.
   b. Press: CONT

6. Three sets of deviates are produced for each sized set. The starting seed as well as the mean and standard deviation are printed and can be compared with the expected values of zero and one respectively.
7. When "WOULD YOU LIKE TO CONSIDER A PARTICULAR DATA SET? (Y/N)" is displayed:

   a. Enter Y if you would like to generate a particular set to be printed out or saved on a mass storage device.
   b. Press: CONT
   c. Go to 8.

   or

   a. Enter N if no particular set is desired.
   b. Press: CONT
   c. At this point, the program is terminated.

8. When "ENTER VALUES FOR THE SIZE OF THE SET, SEED. E.G., 1000,PI" is displayed:

   a. Enter values for the size of the set and the starting seed.
   b. Press: CONT

NOTE: set size must be even.

9. When "WOULD YOU LIKE A PRINTOUT OF THE DATA? (Y/N)" is displayed:

   a. Enter Y if a printout is desired.
   b. Press: CONT
   c. Go to 10.

   or

   a. Enter N if a printout is not desired.
   b. Press: CONT
   c. Go to 12.

10. When "ENTER THE SELECT CODE OF THE PRINTER." is displayed:

    a. Enter the select code of the printer.
    b. Press: CONT

11. When "ENTER THE BUS ADDRESS OF THE PRINTER." is displayed:

    a. Enter the bus address of the printer.
    b. Press: CONT
    c. The data set is then printed on the appropriate device.

12. When "WOULD YOU LIKE TO SAVE THE DATA SET? (Y/N)" is displayed:

    a. Enter Y if you would like it saved.
    b. Press: CONT
    c. Go to 13.

    or

    a. Enter N if you would not like to save it.
    b. Press: CONT
    c. The program is terminated at this point.

13. When "ENTER FILE NAME. FOR EXAMPLE: File:T14 OR DATA:F8" is displayed:

    a. Enter the desired file name.
    b. Press: CONT
    c. The data set is saved on your mass storage device as a vector and the program ends.

RANDOM NORMAL DEVIATES

This program generates sets of Normal random deviates with mean=0 and standard deviation=1. You may use the program in two ways:

1. Directly generate a set of deviates to be printed or saved on a mass storage device.

2. Check through some randomly generated tests in order to get a feel for the quality of the deviates produced. You would then have the option to create your own data set.

The program is set up using the following default values:

1. Sets of size 100, 500, and 1000 are selected in turn.
2. Three tests are performed for each sized set.
3. For each set of data, the mean and standard deviation are calculated. These values can then be compared with the expected mean of 0 and the standard deviation of 1.

Default values may be changed from the keyboard as they come up.

```
SIZE OF RANDOM DEVIATE SETS: 100, 500, 1000

Size of Set:  100
     Seed:    .772190093254      Mean:  -.018     Standard Dev.:   .920
     Seed:    .411868427612      Mean:   .166     Standard Dev.:  1.048
     Seed:    .381347620384      Mean:   .211     Standard Dev.:   .979

Size of Set:  500
     Seed:    .713348741909      Mean:  -.013     Standard Dev.:  1.012
     Seed:    .926291946613      Mean:  -.078     Standard Dev.:  1.015
     Seed:    .011527102207      Mean:   .049     Standard Dev.:  1.026

Size of Set:  1000
     Seed:    .694292955785      Mean:   .037     Standard Dev.:  1.028
     Seed:    .900375816295      Mean:  -.017     Standard Dev.:   .984
     Seed:    .216061505498      Mean:  -.047     Standard Dev.:   .996
```

At this point, you may select a particular data set which you can have printed out or saved on a mass storage device. You will be required to enter the following values: the size of the data set, and the starting seed. For want of a better seed, PI is an excellent choice.

NORMAL DEVIATES:

Seed: .017453292520

I	X(I)	X(I+1)	X(I+2)	X(I+3)	X(I+4)
1	-.278004	-.615298	.745758	-.271614	.708610
6	.631935	.033243	-.478201	-.936948	-.045410
11	-.844072	-.909064	-.605297	.442198	.206267
16	-.810623	-.584475	1.508777	-.513793	.075859
21	-1.387311	.110459	-1.012266	-.495107	.557368

(RNORM1)
Normal Random Deviates With Specified Mean And Standard Deviation

(RNORM1)
Normal Random Deviates With Specified Mean And Standard Deviation

Description

This subprogram generates a set of normal random deviates with mean=Mu and standard deviation=Sigma.

File Name

"RNORM1"

Calling Syntax

CALL Random_normal1 (N,Mu,Sigma,X(*))

Input Parameters

N	number of deviates desired.
Mu	assume a normal distribution with mean=Mu.
Sigma	assume a normal distribution with Standard Deviation=Sigma.

Output Parameters

X(*)	array of dimension (1:N) containing the N normal deviates.

Algorithm

Given a mean = u and standard deviation = s,

1. Generate a deviate x with a normal distribution with mean 0 and standard deviation =1.
2. Then y = u + s * x.

Reference

1. Knuth, Donald E., The Art of Computer Programming, Volume 2 ,Seminumerical Algorithms. Reading, Mass.: Addison-Wesley, 1969, p. 113.

Instructions

1. Insert the RANDOM NUMBER cartridge with the machine turned on.
2. a. Type: LOAD "RNORM1",10
   b. Press: EXECUTE

3. The title "RANDOM NORMAL DEVIATES" is printed along with the options available to you in the program.
4. When "ENTER YOUR CHOICE. [EITHER 1 OR 2]" is displayed:
   a. Enter 1 if you want to directly generate a set of deviates.
   b. Press: CONT
   c. Go to 8.

   or

   a. Enter 2 if you would like to check through some randomly generated examples.
   b. Press: CONT
   c. Go to 5.
5. Default values are supplied for the size of the sets of deviates, the means and standard deviations.
   a. If the default values are satisfactory, simply press: CONT

   or

   a. Change the values as desired.
   b. Press: CONT
6. Three sets of deviates are produced for each sized set. The starting seed as well as the mean and standard deviation are printed and can be compared with the user specified values.
7. When "WOULD YOU LIKE TO CONSIDER A PARTICULAR DATA SET? (Y/N)" is displayed:
   a. Enter Y if you would like to generate a particular set to be printed out or saved on a mass storage device.
   b. Press: CONT
   c. Go to 8.

   or

   a. Enter N if no particular set is desired.
   b. Press: CONT
   c. At this point, the program is terminated.
8. When "ENTER VALUES FOR THE SIZE OF THE SET, SEED, MEAN, SD. E.G., 100,P1,5,2.5" is displayed:
   a. Enter values for the size of the set, the starting seed, the mean and standard deviation.
   b. Press: CONT

9. When "WOULD YOU LIKE A PRINTOUT OF THE DATA (Y/N)" is displayed:

   a. Enter Y if a printout is desired.
   b. Press: CONT
   c. Go to 10.

   or

   a. Enter N if a printout is not desired.
   b. Press: CONT
   c. The program is terminated at this point.

10. When "ENTER THE SELECT CODE OF THE PRINTER." is displayed:

   a. Enter the select code of the printer.
   b. Press: CONT

11. When "ENTER THE BUS ADDRESS OF THE PRINTER." is displayed:

   a. Enter the bus address of the printer.
   b. Press: CONT
   c. The data set is printed out on the appropriate printer.

12. When "WOULD YOU LIKE TO SAVE THE DATA SET? (Y/N)" is displayed:

   a. Enter Y if you would like it saved.
   b. Press: CONT
   c. Go to 13.

   or

   a. Enter N if you would not like it saved.
   b. Press: CONT
   c. The program terminates at this point.

13. When "ENTER FILE NAME. FOR EXAMPLE: File:T14 OR DATA:F8" is displayed:

   a. Enter the desired file name.
   b. Press: CONT
   c. The data set is saved on your mass storage device as a vector and the program ends.

```
                         RANDOM NORMAL DEVIATES

   This program generates sets of Normal random deviates with user-defined
mean and standard deviation.  You may use the program in two ways:

     1.  Directly generate a set of deviates to be printed or saved on a mass
         storage device.

     2.  Check through some randomly generated tests in order to get a feel for
         the quality of the deviates produced.  You would then have the option
         to create your own data set.

   The program is set up using the following default values:

   1. Five different sets of means and standard deviations are used:
       (.5,.5), (2,.5), (.5,2), (10,1), and (1,10).
   2. Three tests are performed for each mean and standard deviation using 100
      normal random numbers for each set.
   3. For each test, the mean and standard deviation are calculated.  These
      values can then be compared with the expected mean and standard deviation.

   Default values may be changed from the keyboard as they come up.

# OF DIFFERENT MEANS AND SDs: 5

Mean:     .50      Standard Deviation:     .50
     Seed:     .882190093254       Mean:    .530     Standard Dev.:    .524
     Seed:     .921869427612       Mean:    .558     Standard Dev.:    .481
     Seed:     .291347620384       Mean:    .570     Standard Dev.:    .513

Mean:    2.00      Standard Deviation:     .50
     Seed:     .023348743108       Mean:   2.062     Standard Dev.:    .541
     Seed:     .636292953813       Mean:   2.067     Standard Dev.:    .526
     Seed:     .122374157495       Mean:   1.969     Standard Dev.:    .500

Mean:     .50      Standard Deviation:    2.00
     Seed:     .916666453150       Mean:    .782     Standard Dev.:   2.249
     Seed:     .916487097727       Mean:    .683     Standard Dev.:   1.999
     Seed:     .765649188925       Mean:    .495     Standard Dev.:   2.394

Mean:   10.00      Standard Deviation:    1.00
     Seed:     .910967885226       Mean:   9.976     Standard Dev.:   1.051
     Seed:     .123991476468       Mean:   9.847     Standard Dev.:   1.001
     Seed:     .276831709552       Mean:   9.929     Standard Dev.:    .958

Mean:    1.00      Standard Deviation:   10.00
     Seed:     .815467733295       Mean:   -.773     Standard Dev.:  10.448
     Seed:     .809363702464       Mean:   2.434     Standard Dev.:   8.962
     Seed:     .833873773547       Mean:   2.005     Standard Dev.:   9.335
```

At this point, you may select a particular data set which you can have printed out or saved on a mass storage device. You will be required to enter the following values: the size of the data set, the starting seed, and the desired mean and standard deviation. For want of a better seed, PI is an excellent choice!

NORMAL DEVIATES:

Seed: .017453292520 Mean: 5.0000 Sd: 2.5000

I	X(I)	X(I+1)	X(I+2)	X(I+3)	X(I+4)
1	4.304991	3.461756	6.864396	4.320965	6.771525
6	6.579839	5.083108	3.804498	2.657631	4.886475
11	4.839820	2.727340	3.486757	6.105494	5.515667
16	2.973442	3.538813	8.771944	3.715517	5.189646
21	1.531723	5.276148	2.469335	3.762231	6.393420

(RNORM2)
Dependent Normally Distributed Random Variables

(RNORM2)
Dependent Normally Distributed Random Variables (Bivariate Normal Deviates)

Description

This subprogram generates two dependent random variables, normally distributed with mean=Mu1,Mu2, standard deviation =Sigma1,Sigma2, and Correlation Coefficient=Rho.

File Name

"RNORM2"

Calling Syntax

CALL Random_normal2 (Mu1,Mu2,,Sigma1,Sigma2,Rho,X1(*),X2(*))

Input Parameters

MU1, Mu2	initial means.
Sigma1, Sigma2	initial standard deviations.
Rho	initial correlation coefficient.

Output Parameters

X1(*), X2(*)	two vectors of dependent normally distributed random variables.

Algorithm

If x1 and x2 are independent normal deviates with mean=0 and standard deviation=1, and if y1=Mu1+Sigma1*x1 and y2=Mu2+Sigma2* (Rho*x1+ $\sqrt{1-Rho\wedge 2}$*x2)

then y1 and y2 are dependent random variables, normally distributed with means Mu1, Mu2 and standard deviations Sigma1 and Sigma2, and with correlation coefficient Rho.

Reference

1. Knuth, Donald E., The Art of Computer Programming, Volume 2 Seminumerical Algorithms. Reading, Mass.: Addison-Wesley, 1969, p. 113.

Instructions

1. Insert the RANDOM NUMBER cartridge with the machine turned on.
2. a. Type: LOAD "RNORM2",10
   b. Press: EXECUTE

3. The title "DEPENDENT NORMAL RANDOM DEVIATES" is printed along with the options available to you in the program.
4. When "ENTER YOUR CHOICE. [EITHER 1 OR 2]" is displayed:

   a. Enter 1 if you want to directly generate a set of deviates.
   b. Press: CONT
   c. Go to 8.

   or

   a. Enter 2 if you would like to check through some randomly generated examples.
   b. Press: CONT
   c. Go to 5.

5. Default values are supplied for the size of the sets of deviates, the means, standard deviations and correlation coefficient.

   a. If the default values are satisfactory, simply press: CONT

   or

   a. Change the values as desired.
   b. Press: CONT

6. Three sets of deviates are produced for each sized set. The starting seed, means, standard deviations and correlation coefficient are printed as well as the calculated means, standard deviations and correlation coefficient between the two sets of deviates.
7. When "WOULD YOU LIKE TO CONSIDER A PARTICULAR DATA SET? (Y/N)" is displayed:

   a. Enter Y if you would like to generate a particular set to be printed out or saved on a mass storage device.
   b. Press: CONT
   c. Go to 8.

   or

   a. Enter N if no particular set is desired.
   b. Press: CONT
   c. At this point, the program is terminated.

8. When "ENTER VALUES FOR THE SIZE OF THE SET, SEED, CORRELATION COEFFICIENT. E.G., 100,PI,.7" is displayed:

   a. Enter values for the size of the set, the starting seed, and the correlation coefficient.
   b. Press: CONT

9. When "ENTER VALUES FOR THE FIRST MEAN, STANDARD DEVIATION. E.G., 5,1" is displayed:

   a. Enter values for the first mean and standard deviation.

   b. Press: CONT

10. When "ENTER VALUES FOR THE SECOND MEAN, STANDARD DEVIATION. E.G., 12,3.5" is displayed:

    a. Enter values for the second mean and standard deviation.

    b. Press: CONT

11. After the data set has been created, the prompt: "WOULD YOU LIKE THE DATA SET STORED ON A MASS STORAGE DEVICE? (Y/N)" will be displayed:

    a. Enter Y if you would like it saved.

    b. Press: CONT

    c. Go to 12.

    or

    a. Enter N if a printout is not desired.

    b. Press: CONT

    c. Go to 14.

12. When "ENTER THE SELECT CODE OF THE PRINTER," is displayed:

    a. Enter the select code of the printer.

    b. Press: CONT

13. When "ENTER THE BUS ADDRESS OF THE PRINTER." is displayed:

    a. Enter the bus address of the printer.

    b. Press: CONT

    c. The data set is then printed out on the appropriate device.

14. When "WOULD YOU LIKE TO SAVE THE DATA SET? (Y/N)" is displayed:

   a. Enter Y if you would like it saved.
   b. Press: CONT
   c. Go to 15.

   or

   a. Enter N if you would not like it saved.
   b. Press: CONT
   c. The program is terminated at this point.

15. When "ENTER FILE NAME. FOR EXAMPLE:T14 OR DATA:F8" is displayed:

   a. Enter the desired file name.
   b. Press: CONT
   c. The data set is saved on your mass storage device as a vector and the program ends.

DEPENDENT NORMAL RANDOM DEVIATES

This program generates a set of dependent Normal random deviates with user defined means and standard deviations. You may use the program in two ways:

1. Directly generate a set of deviates to be printed or saved on a mass storage device.

2. Check through some randomly generated tests in order to get a feel for the quality of the deviates produced. You would then have the option to create your own data set.

The program is set up using the following default values:

1. Mean1 = 0.0 Standard Dev1 = 1.0
   Mean2 = 2.0 Standard Dev2 = 5.0
   Correlation Coefficient = 0.7

2. Three tests, using 100 deviates from each set will be performed.

3. For each test, the means and standard deviations are calculated, as well as the coefficient of correlation.

Default values may be changed from the keyboard as they come up.

```
# OF DEVIATES FOR EACH SET: 1000
MEAN1:  0.000     SD1:  1.000
MEAN2:  5.000     SD2:  2.000
CORRELATION COEFFICIENT: .5

Seed: .712190093254       Mean1:    .011     Standard Dev1:  1.023
                          Mean2:   4.915     Standard Dev2:  2.048
        Correlation Coefficient:    .498

Seed: .951868427612       Mean1:    .077     Standard Dev1:   .941
                          Mean2:   4.994     Standard Dev2:  1.948
        Correlation Coefficient:    .479

Seed: .521347620384       Mean1:    .015     Standard Dev1:  1.035
                          Mean2:   5.100     Standard Dev2:  2.035
        Correlation Coefficient:    .530
```

At this point, you may select a particular data set which you can have printed out or saved on a mass storage device. You will be required to enter the following values: the size of the data set, the starting seed, the two means and standard deviations, and the correlation coefficant. For want of a better seed, PI is an excellent choice!

DEPENDENT NORMAL DEVIATES:

```
Seed:      .017453292520
Mean1:    5.0000     Sd1:   1.0000
Mean2:   12.0000     Sd2:   3.5000     Rho: .7000
```

I	X(I)	X(I+1)	X(I+2)	X(I+3)	X(I+4)
1	1.663956	-2.383572	13.949101	1.740634	13.503322
6	12.583226	5.398920	-.738410	-6.243373	4.455081
11	4.471136	-5.908770	-2.263564	10.306370	7.475200
16	-4.727476	-2.013696	23.105329	-1.165518	5.910302
21	-11.647728	6.325512	-7.147192	-.941289	-12.209863

I	Y(I)	Y(I+1)	Y(I+2)	Y(I+3)	Y(I+4)
1	6.469833	-4.434210	38.568919	4.471587	34.794196
6	33.155234	11.758055	-7.325937	-16.525786	10.264808
11	14.649641	-14.484984	-4.698050	28.247726	18.309951
16	-8.855412	-4.711909	57.046057	.454459	13.826361
21	-26.004736	16.456228	-18.109722	-1.783696	-32.029985

(RPAR1)
Random Pareto Generator
Of the First Kind

(RPAR1)
Random Pareto Generator Of The First Kind

Description

This program generates sets of random Pareto deviates of the first kind. The density function is defined as follows:

$$f(X) = [N^*A\wedge N]/X\wedge(N+1) \qquad \text{for } X > A$$

File Name

"RPAR1"

Calling Syntax

CALL Random_pareto1 (Number,A,N,X(*))

Input Parameters

Number	number of random deviates desired.
A,N	Pareto parameters.

Output Parameters

X(*)	array of dimension (1:N) containing N Pareto deviates of the first kind.

Algorithm

1. Given parameters A and N, generate a uniform deviate U.
2. Then the Pareto deviate is equal to: A/(1-U)∧(1/N).

Instructions

1. Insert the RANDOM NUMBER cartridge with the machine turned on.
2. a. Type: LOAD "RPAR1",10
   b. Press: EXECUTE
3. The title "RANDOM PARETO DEVIATES OF THE FIRST KIND" is printed along with some introductory remarks.
4. When "ENTER VALUES FOR THE SIZE OF THE SET, SEED, A, N. E.G. 100, PI,10,.8" is displayed:

   a. Enter values for the size of the set, the starting seed, and the Pareto parameters A and N.
   b. Press: CONT

5. After the data set has been created, the prompt: "WOULD YOU LIKE A PRINTOUT OF THE DATA? (Y/N)" is displayed:

   a. Enter Y if a printout is desired.
   b. Press: CONT
   c. Go to 6.

   or

   a. Enter N if a printout is not desired.
   b. Press: CONT
   c. Go to 8.

6. When "ENTER THE SELECT CODE OF THE PRINTER." is displayed:

   a. Enter the select code of the printer.
   b. Press: CONT

7. When "ENTER THE BUS ADDRESS OF THE PRINTER." is displayed:

   a. Enter the bus address of the printer.
   b. Press: CONT

8. When "WOULD YOU LIKE TO SAVE THE DATA SET? (Y/N)" is displayed:

   a. Enter Y if you would like it saved.
   b. Press: CONT
   c. Go to 9.

   or

   a. Enter N if you would not like it saved.
   b. Press: CONT
   c. At this point, the program terminates.

9. When "ENTER FILE NAME. FOR EXAMPLE, File:T14 OR DATA:F8" is displayed:

   a. Enter the desired file name.
   b. Press: CONT
   c. The data set is saved on your mass storage device as a vector and the program ends.

RANDOM PARETO DEVIATES OF THE FIRST KIND

This program generates sets of Pareto deviates of the First kind. The density function is defined as follows: f(X)=[N*A^N]/X^(N+1) for X>A. The corresponding distribution function is: F(X)=1-(A/X)^N for X>A.

In this program, you may select a particular data set which you can have printed out or saved on a mass storage device. You will be required to enter the following values: the size of the data set, the starting seed, and the parameters A and N. For want of a better seed, PI is an excellent choice!

PARETO I DEVIATES:

Seed: .01745329252 A: 10.000 N: .800

I	X(I)	X(I+1)	X(I+2)	X(I+3)	X(I+4)
1	16.084997	11.304425	180.885864	17.260754	73.783520
6	61.325641	25.885165	10.375376	11.395074	22.677573
11	22.663491	11.313336	10.006642	58.127092	281.523852
16	344.635942	12.237704	58.400460	31.784333	11.300812
21	19.181864	54.464768	10.490970	28.574731	13.071547

(RPAR2) Random Pareto Generator of the Second Kind

(RPAR2)
Random Pareto Generator Of The Second Kind

Description

This program generates sets of random Pareto deviates of the second kind. The density function is defined as follows:

f(X) = [N*B∧N]/[B+X]∧(N+1)   for x>0.

File Name

"RPAR2"

Calling Syntax

CALL Random_pareto2 (Number,B,N,X(*))

Input Parameters

Number	number of random deviates desired.
B,N	Pareto parameters.

Output Parameters

X(*)	array of dimension(1:N) containing N Pareto deviates of the second kind.

Algorithm

1. Given parameters B and N, generate a uniform deviate U.
2. Then the Pareto deviate is equal to: B/(1-U)∧(1/N)-B.

Instructions

1. Insert the RANDOM NUMBER cartridge with the machine turned on.
2. a. Type: LOAD "RPAR2",10
   b. Press: EXECUTE
3. The title "RANDOM PARETO DEVIATES OF THE SECOND KIND" is printed along with some introductory remarks.
4. When "ENTER VALUES FOR THE SIZE OF THE SET, SEED, B, N. E.G. 100, PI,10,.8" is displayed:

   a. Enter values for the size of the set, the starting seed, and the Pareto parameters B and N.

   b. Press: CONT

5. After the data set has been created, the prompt: "WOULD YOU LIKE A PRINTOUT OF THE DATA? (Y/N)" is displayed:

   a. Enter Y if a printout is desired.
   b. Press: CONT
   c. Go to 6.

   or

   a. Enter N if a printout is not desired.
   b. Press: CONT
   c. Go to 8.

6. When "ENTER THE SELECT CODE OF THE PRINTER." is displayed:

   a. Enter the select code of the printer.
   b. Press: CONT

7. When "ENTER THE BUS ADDRESS OF THE PRINTER." is displayed:

   a. Enter the bus address of the printer.
   b. Press: CONT

8. When "WOULD YOU LIKE TO SAVE THE DATA SET? (Y/N)" is displayed:

   a. Enter Y if you would like it saved.
   b. Press: CONT
   c. Go to 9.

   or

   a. Enter N if you would not like it saved.
   b. Press: CONT
   c. At this point, the program terminates.

9. When "ENTER FILE NAME. FOR EXAMPLE, File:T14 OR DATA:F8" is displayed:

   a. Enter the desired file name.
   b. Press: CONT
   c. The data set is saved on your mass storage device as a vector and the program ends.

RANDOM PARETO DEVIATES OF THE SECOND KIND

This program generates sets of Pareto deviates of the Second kind. The density function is defined as follows: f(X)=[N*B^N]/[B+X]^(N+1) for X>0. The corresponding distribution function is: F(X)=1-[B/(B+X)]^N.

In this program, you may select a particular data set which you can have printed out or saved on a mass storage device. You will be required to enter the following values: the size of the data set, the starting seed, and the parameters B and N. For want of a better seed, PI is an excellent choice!

PARETO II DEVIATES:

Seed: .017453292520 B: 10.000 N: .800

I	X(I)	X(I+1)	X(I+2)	X(I+3)	X(I+4)
1	6.084997	1.304425	170.885864	7.260754	63.783520
6	51.325641	15.885165	.375376	1.395074	12.677573
11	12.663491	1.313336	.006642	49.127082	271.523852
16	234.635942	2.237704	48.400480	21.784333	1.300812
21	9.181864	44.464768	.490970	19.574731	3.071547

(RPOISS)
Random Integers Generated From a Poisson Distribution

(RPOISS)
Random Integers Generated From A Poisson Distribution

Description

This subprogram generates a set of Poisson deviates with a specified mean.

File Name

"RPOISS"

Calling Syntax

CALL Random_poisson (N,Mu,X(*))

Input Parameters

N	number of random integers desired.
Mu	mean of the Poisson distribution.

Output Parameters

X(*)	array of dimension (1:N) containing integers randomly generated with the given Poisson distribution.

Algorithm

Given a mean of the distribution m,

1. Set: P=exp(−M)
   N=0
   Q=1
2. Generate a random variable U, uniformly distributed between 0 and 1.
3. Set: Q=Q*U
4. If Q>P, then set N=N+1 and return to step 2.

   Else, terminate the algorithm with output N.

Reference

1. Knuth, Donald E., The Art of Computer Programming, Volume 2 Seminumerical Algorithms. Reading, Mass.: Addison-Wesley, 1969, p. 117.

Instructions

1. Insert the RANDOM NUMBER cartridge with the machine turned on.

2. a. Type: LOAD "RPOISS",10
   b. Press: EXECUTE
3. The title "RANDOM POISSON DEVIATES" is printed along with the options available to you in the program.
4. When "ENTER YOUR CHOICE. [EITHER 1 OR 2]" is displayed:

   a. Enter 1 if you want to directly generate a set of deviates.

   b. Press: CONT

   c. Go to 8.

   or

   a. Enter 2 if you would like to check through some randomly generated examples.

   b. Press: CONT

   c. Go to 5.

5. Default values are supplied for the size of the sets of deviates, and the probabilities.

   a. If the default values are satisfactory, simply press: CONT

   or

   a. Change the values as desired.

   b. Press: CONT

6. Three sets of deviates with different starting seeds are produced for each mean. After each data set is generated, the starting seed, the mean and the variance of the set are printed.
7. When "WOULD YOU LIKE TO CONSIDER A PARTICULAR DATA SET? (Y/N)" is displayed:

   a. Enter Y if you would like to generate a particular set to be printed out or saved on a mass storage device.

   b. Press: CONT

   or

   a. Enter N if no particular set is desired.

   b. Press: CONT

   c. At this point, the program is terminated.

8. When "ENTER VALUES FOR THE SIZE OF THE SET, SEED, MEAN. E.G. 100, PI,5" is displayed:

   a. Enter values for the size of the set, the starting seed, the mean of the distribution.

   b. Press: CONT

9. After the data set has been created, the prompt: "WOULD YOU LIKE A PRINTOUT OF THE DATA? (Y/N)" is displayed:

   a. Enter Y if a printout is desired.
   b. Press: CONT
   c. Go to 10.

   or

   a. Enter N if a printout is not desired.
   b. Press: CONT
   c. Go to 12.

10. When "ENTER THE SELECT CODE OF THE PRINTER." is displayed:

    a. Enter the select code of the printer.
    b. Press: CONT

11. When "ENTER THE BUS ADDRESS OF THE PRINTER." is displayed:

    a. Enter the bus address of the printer
    b. Press: CONT

12. When "WOULD YOU LIKE TO SAVE YOUR DATA SET? (Y/N)" is displayed:

    a. Enter Y if you would like it saved.
    b. Press: CONT
    c. Go to 13.

    or

    a. Enter N if you would not like it saved.
    b. Press: CONT
    c. At this point, the program terminates.

13. When "ENTER FILE NAME. FOR EXAMPLE, File:T14 OR DATA:F8" is displayed:

    a. Enter the desired file name.
    b. Press: CONT
    c. The data set is saved on your mass storage device as a vector and the program ends.

RANDOM POISSON DEVIATES

This program generates sets of Poisson random deviates. You may use the program in two ways:

1. Directly generate a set of deviates to be printed or saved on a mass storage device.

2. Check through some randomly generated tests in order to get a feel for the quality of the deviates produced. You would then have the option to create your own data set.

This program generates sets of Poisson random deviates. It also compares the resulting data with the theoretical expectations. In particular, the mean and variance of each set of Poisson random numbers is calculated. The expected value of both is the Poisson parameter from which the data was generated.

The program is set up using the following default values:

1. A random seed is generated.
2. 0.5, 3.5, 6.5, and 9.5 are selected in turn as the Poisson parameters.
3. For each parameter, 3 sets of 100 Poisson deviates along with their corresponding mean and variance are calculated.
4. The resulting data is printed for each set.

Default values may be changed from the keyboard as they come up.

The primary purpose of this driver program is to allow you to check out our Poisson subprogram. This subprogram may then be used in your own context.

```
# OF POISSON DEVIATES: 1000
POISSON PARAMETERS: 0.5, 3.5, 6.5, 9.5

Poisson Parameter:  .5
  Seed: .582190093254       Mean:    .478      Variance:    .480
  Seed: .621868427612       Mean:    .507      Variance:    .508
  Seed: .991347620344       Mean:    .483      Variance:    .488
                  Mean St. Dev.:     .016

Poisson Parameter:  3.5
  Seed: .723348710080       Mean:   3.527      Variance:   3.837
  Seed: .336265176712       Mean:   3.534      Variance:   3.454
  Seed: .799013614990       Mean:   3.507      Variance:   3.195
                  Mean St. Dev.:     .014

Poisson Parameter:  6.5
  Seed: .970450206394       Mean:   6.475      Variance:   6.370
  Seed: .149623576655       Mean:   6.563      Variance:   6.773
  Seed: .992427966783       Mean:   6.454      Variance:   5.952
                  Mean St. Dev.:     .058
```

Poisson Parameter: 9.5

Seed: .631920064311	Mean: 9.502	Variance: 8.913
Seed: .444774065081	Mean: 9.518	Variance: 9.247
Seed: .055005551705	Mean: 9.234	Variance: 9.705
Mean St. Dev.:	.160	

At this point, you may select a particular data set which you can have printed out or saved on a mass storage device. You will be required to enter the following values: the size of the data set, the starting seed, and the Mean. For want of a better seed, PI is an excellent choice.

POISSON DEVIATES:

Seed: .017453292520 Mean: 5.0000

I	X(I)	X(I+1)	X(I+2)	X(I+3)	X(I+4)
1	5.000000	2.000000	3.000000	6.000000	3.000000
6	3.000000	10.000000	5.000000	4.000000	4.000000
11	4.000000	4.000000	6.000000	5.000000	7.000000
16	5.000000	5.000000	7.000000	3.000000	5.000000
21	4.000000	4.000000	5.000000	2.000000	4.000000

(RSPHER)
Random Points on an M-dimensional Sphere of Radius One

(RSPHER)
Random Points on an M-dimensional Sphere of Radius One

Description

This subprogram generates a set of random points on an M-dimensional sphere of radius one.

File Name

"RSPHER"

Calling Syntax

CALL Random_sphere (N,M,X(*))

Input Parameters

N	number of random points desired.
M	number of dimensions of the sphere.

Output Parameters

X(*)	array of dimension (1:N) containing the N random points.

Algorithm

1. Let X1, X2 . . . , Xm be independent normal deviates (mean=0, standard deviation=1).
2. Let R=SQR(X1∧2+X2∧2+...+Xm∧2).
3. Then the point (X1/R,X2/R,...,Xm/R) is a random point on the M dimensional sphere of radius one.

Reference

1. Knuth, Donald E., The Art of Computer Programming, Volume 2 Seminumerical Algorithms. Reading, Mass.: Addison-Wesley, 1969, p. 116.

Instructions

1. Insert the RANDOM NUMBER cartridge with the machine turned on.
2. a. Type: LOAD "RSPHER",10
   b. Press: EXECUTE
3. The title "RANDOM PTS. ON AN M-DIMENSIONAL SPHERE" is printed along with the options available to you in the program.

4. When "# OF POINTS DESIRED?" is displayed:
   a. Enter the number of points desired.
   b. Press: CONT
5. When "DIMENSIONS OF THE SPHERE?" is displayed:
   a. Enter the dimensions of the sphere.
   b. Press: CONT
6. When "ENTER A STARTING SEED." is displayed:
   a. Enter a starting seed. For want of a better seed, PI/180 is an excellent choice.
   b. Press: CONT
7. When "WOULD YOU LIKE A PRINTOUT OF THE DATA? (Y/N)" is displayed:
   a. Enter Y if a printout is desired.
   b. Press: CONT
   c. Go to 8.

   or

   a. Enter N if a printout is not desired.
   b. Press: CONT
   c. Go to 10.
8. When "ENTER THE SELECT CODE OF THE PRINTER." is displayed:
   a. Enter the select code of the printer.
   b. Press: CONT
9. When "ENTER THE BUS ADDRESS OF THE PRINTER." is displayed:
   a. Enter the bus address of the printer.
   b. Press: CONT
   c. The data set is then printed out on the appropriate printer.

10. When "WOULD YOU LIKE TO SAVE THE DATA SET? (Y/N)" is displayed:

    a. Enter Y if you would like it saved.
    b. Press: CONT
    c. Go to 11.

    or

    a. Enter N if you would not like it saved.
    b. Press: CONT
    c. The program is terminated at this point.

11. When "ENTER FILE NAME. FOR EXAMPLE: File:T14 OR DATA:F8" is displayed:

    a. Enter the desired file name.
    b. Press: CONT
    c. The data set is saved on your mass storage device as a vector, and the program ends.

```
                    RANDOM PTS. ON AN M-DIMENSIONAL SPHERE

   This program generates sets of uniformly distributed random points on an
M-dimensional sphere.

   You will be required to enter the number of points desired and the dimensions
of the sphere.  You will then be given the options of printing out the
generated data and storing it on a mass storage device.

# OF POINTS DESIRED:  12
DIMENSIONS OF THE SPHERE:  3
SEED: .882190093254



UNIFORM DEVIATES ON AN M-DIMENSIONAL SPHERE:

   Seed: .882190093254

   1      .946119    -.295299     .132880
   2    -.900914      .178396     .395637
   3    -.262349    -.283895      .922267
   4      .118382    -.418917     .900274
   5    -.058066      .734255     .676386
   6      .020370    -.998962    -.040748
   7    -.991123      .098869    -.088884
   8    -.040587      .034705    -.998573
   9    -.943735      .222579    -.244585
  10      .124431     .570977     .811481
  11    -.199613      .979732    -.016728
  12    -.683251      .380686     .623094
```

(RSUPER)
Super Uniform Random Number Generator

(RSUPER)
Super Uniform Random Number Generator

Description

Given methods for generating two random sequences, this algorithm successfully outputs the terms of a 'considerably more random' sequence. This routine uses both IRND and RND, generates 'super' random numbers and, due to the slow execution speed, should be used only in cases where no regular random number generator will do.

File Name

"RSUPER"

Calling Syntax

CALL Random_super (N,X(*))

Input Parameters

N	number of random deviates desired.

Output Parameters

X(*)	array of dimension (1:N) containing N uniformly generated random numbers on the range (0,1).

Algorithm

This method has been suggested by MacLauren and Marsaglia (Ref. 1). Given methods for generating two pseudo-random sequences xn and yn, this routine will output terms of a 'considerably more random' sequence.

A temporary table V(1:100) is used as well as the modulus M used in the generation of sequence yn.

1. Fill table V with the first 100 elements of sequence Xn.
2. Set X,Y equal to the next numbers of the sequences Xn, Yn respectively.
3. Set J=INT(101*Y/M+1)
4. Output V(J) and set V(J)=X.
   Go to step 2.

In our routine, sequence Xn is generated using RND and sequence Yn using IRND.

Knuth contends that the sequence obtained by applying this algorithm will satisfy virtually anyone's requirements for randomness in a computer generated sequence.

Reference

1. Knuth, Donald E., The Art of Computer Programming, Vol. II, Seminumerical Algorithms Reading, Mass.: Addison-Wesley, 1969, p. 30.

Special Considerations

1. As a result of our own tests, this generator comes highly recommended. It performed extremely well on all of our tests of randomness. In terms of execution speed and storage space, it is approximately three times as slow as either RND or IRND alone, plus it requires an extra 800 or so bytes for storage of the temporary array.
2. In using this routine, it is suggested that as many random deviates be generated on one call as is possible. Each time the subprogram is entered, 101 new table values are created.
3. If you are interested in repeatability of an experiment, remember that initial seeds must be set for both IRND (using SEED) and RND (using RANDOMIZE).
4. If you plan on calling this routine a large number of times, a significant amount of time would be saved if the table V is set up once in your calling routine and then passed as an additional parameter to Random_super. This will avoid the overhead of redoing this table each time you enter the routine.

Instructions

1. Insert the RANDOM NUMBER cartridge with the machine turned on.
2. a. Type: LOAD "RSUPER",10
   b. Press: EXECUTE
3. The title "SUPER RANDOM NUMBER GENERATOR" is printed along with options available to you in the program.
4. When "ENTER YOUR CHOICE. [EITHER 1 OR 2]" is displayed:

   a. Enter 1 if you want to directly generate a set of deviates.

   b. Press: CONT

   c. Go to 8.

   or

   a. Enter 2 if you would like to check through some randomly generated examples using a standard Chi-square test.

   b. Press: CONT

   c. Go to 5.

5. Default values are supplied for the size of the sets of deviates, and number of categories to be used in the Chi-square test.

   a. If the default values are satisfactory, simply press: CONT

   or

   a. Change the values as desired.
   b. Press: CONT

6. Three sets of deviates with different starting seeds are produced and a Chi-square test is performed for each data set. The starting seed, the Chi-square statistic and the right-tailed probability are printed.

7. When "WOULD YOU LIKE TO CONSIDER A PARTICULAR DATA SET? (Y/N)" is displayed:

   a. Enter Y if you would like to generate a particular set to be printed out or saved on a mass storage device.
   b. Press: CONT

   or

   a. Enter N if no particular set is desired.
   b. Press: CONT
   c. At this point, the program is terminated.

8. When "ENTER VALUES FOR THE SIZE OF THE SET, SEED. E.G. 100, PI" is displayed:

   a. Enter values for the size of the set and the starting seed.
   b. Press: CONT

9. After the data set has been created, the prompt: "WOULD YOU LIKE A PRINTOUT OF THE DATA? (Y/N)" is displayed:

   a. Enter Y if a printout is desired.
   b. Press: CONT
   c. Go to 10.

   or

   a. Enter N if a printout is not desired.
   b. Press: CONT
   c. Go to 12.

10. When "ENTER THE SELECT CODE OF THE PRINTER." is displayed:

    a. Enter the select code of the printer.

    b. Press: CONT

11. When "ENTER THE BUS ADDRESS OF THE PRINTER." is displayed:

    a. Enter the bus address of the printer.

    b. Press: CONT

12. When "WOULD YOU LIKE TO SAVE THE DATA SET? (Y/N)" is displayed:

    a. Enter Y if you would like it saved.

    b. Press: CONT

    c. Go to 13.

    or

    a. Enter N if you would not like it saved.

    b. Press: CONT

    c. At this point, the program terminates.

13. When "ENTER FILE NAME. FOR EXAMPLE, File:T14 OR DATA:F8" is displayed:

    a. Enter the desired file name.

    b. Press: CONT

    c. The data set is saved on your mass storage device as a vector and the program ends.

SUPER RANDOM NUMBER GENERATOR

This program tests the super random number generator for randomness. This generator combines the two generators RND and IRND to produce a significantly more uniform pseudo-random sequence. It takes approximately 800 extra bytes and is about three times as slow as IRND.

The program may be used in the following ways:

1. Directly generate a set of deviates to be printed or saved on a mass storage device.

2. Check through some randomly generated tests in order to get a feel for the quality of the deviates produced. You would then have the option to create your own data set.

A series of Chi-square tests will be run on the generator. You will be required to enter values for the number of observations and the number of categories to be used in the Chi-square tests. Default values are provided for each input.

NUMBERS OF OBSERVATIONS: 1000
NUMBER OF CATEGORIES: 100

The resulting Chi-square statistic and the corresponding right-tailed probability will be printed for each test.

```
# OF OBSERVATIONS:  1000
     Seed: .622190093248      V:    79.4      Prob (X>V): .926
     Seed: .431461189657      V:   113.4      Prob (X>V): .153
     Seed: .086158972901      V:   106.8      Prob (X>V): .278
```

At this point, you may select a particular data set which you can have printed out or saved on a mass storage device. You will be required to enter the following values: the total number of observations and the starting seed. For want of a better seed, PI/180 is an excellent choice!

SUPER UNIFORM RANDOM DEVIATES:

Seed: .017453292520

I	X(I)	X(I+1)	X(I+2)	X(I+3)	X(I+4)
1	.807840	.724974	.908970	.832369	.249594
6	.661944	.447893	.358119	.703196	.562812
11	.523675	.874582	.987723	.790323	.383725
16	.712651	.815226	.444412	.170364	.245539
21	.171834	.281558	.178072	.603049	.399430

(RT)
Random Numbers Generated From a T-Distribution

(RT)
Random Numbers Generated From A T-Distribution

Description

This subprogram generates a set of random deviates for a T-distribution with V degrees of freedom.

File Name

"RT"

Calling Syntax

CALL Random_t (N,V,X(*))

Input Parameters

N	number of random deviates desired.
V	degrees of freedom.

Output Parameters

X(*)	array of dimension (1:N) containing the N random deviates.

Algorithm

1. Let y1 be a normal deviate. (mean=0, standard deviation=1)
2. Let y2 be independent of y1, having the Chi-square distribution with v degrees of freedom.
3. Then x=y1/(SQR(y2/v)) is independent, having the T distribution with v degrees of freedom.

Reference

1. Knuth, Donald E., The Art of Computer Programming, Volume 2 Seminumerical Algorithms. Reading, Mass.: Addison-Wesley, 1969, p. 116.

Instructions

1. Insert the RANDOM NUMBER cartridge with the machine turned on.
2. a. Type: LOAD "RT",10
   b. Press: EXECUTE
3. The title "RANDOM T DEVIATES" is printed along with the options available to you in the program.

4. When "ENTER YOUR CHOICE. [EITHER 1 OR 2]" is displayed:

   a. Enter 1 if you want to directly generate a set of deviates.

   b. Press: CONT

   c. Go to 8.

   or

   a. Enter 2 if you would like to check through some randomly generated examples.

   b. Press: CONT

   c. Go to 5.

5. Default values are supplied for the size of the sets of deviates, and the T parameter.

   a. If the default values are satisfactory, simply press: CONT

   or

   a. Change the values as desired.

   b. Press: CONT

6. Three sets of deviates are produced for each T parameter. The starting seed, mean, and variance are printed as well as the expected mean and variance.

7. When "WOULD YOU LIKE TO CONSIDER A PARTICULAR DATA SET? (Y/N)" is displayed:

   a. Enter Y if you would like to generate a particular set to be printed out or saved on a mass storage device.

   b. Press: CONT

   c. Go to 8.

   or

   a. Enter N if no particular set is desired.

   b. Press: CONT

   c. At this point, the program is terminated.

8. When "ENTER VALUES FOR THE SIZE OF THE SET, SEED, DEGREE OF FREEDOM. E.G., 10,PI,5" is displayed:

   a. Enter values for the size of the set, the starting seed, and the T parameter.

   b. Press: CONT

9. When "WOULD YOU LIKE A PRINTOUT OF THE DATA? (Y/N)" is displayed:

   a. Enter Y if a printout is desired.

   b. Press: CONT

   c. Go to 10.

   or

   a. Enter N if a printout is not desired.

   b. Press: CONT

   c. Go to 12.

10. When "ENTER THE SELECT CODE OF THE PRINTER." is displayed:

    a. Enter the select code of the printer.

    b. Press: CONT

11. When "ENTER THE BUS ADDRESS OF THE PRINTER." is displayed:

    a. Enter the bus address of the printer.

    b. Press: CONT

    c. The data set is then printed out on the appropriate device.

12. When "WOULD YOU LIKE TO SAVE THE DATA SET? (Y/N)" is displayed:

    a. Enter Y if you would like it saved.

    b. Press: CONT

    c. Go to 13.

    or

    a. Enter N if you would not like it saved.

    b. Press: CONT

    c. The program is terminated at this point.

13. When "ENTER FILE NAME. FOR EXAMPLE: File:T14 OR DATA:F8" is displayed:

    a. Enter the desired file name.

    b. Press: CONT

    c. The data set is saved on your mass storage device as a vector, and the program ends.

RANDOM T DEVIATES

This program generates sets of T(V) random deviates. You may use the program in two ways:

1. Directly generate a set of deviates to be printed or saved on a mass storage device.

2. Check through some randomly generated tests in order to get a feel for the quality of the deviates produced. You would then have the option to create your own data set.

This program generates sets of T(V) random deviates. It also compares the resulting data with the theoretical expectations. In particular, given V degrees of freedom, the mean and variance of each set of T random numbers is calculated.

The expected value of the mean is: 0
The expected value of the variance is: V/(V-2) for V>2.

The program is set up using the following default values:

1. 50 deviates will be generated for each T parameter.
2. Values for V, the degrees of freedom, are set at 5, 10, and 50.
3. Results printed are:
   - mean, expected mean, and standard deviation for each set.
   - variance and expected variance for each set.

Default values may be changed from the keyboard as they come up.

```
# OF RANDOM DEVIATES: 1000
DEGREES OF FREEDOM: 5, 10, 50


V:  5

       Seed:    .225190093254
       Mean:    .044        Expected Mean:    0.000     Standard Dev.:   1.359
   Variance:   1.846     Expected Variance:   1.667

       Seed:    .384868426712
       Mean:    .043        Expected Mean:    0.000     Standard Dev.:   1.245
   Variance:   1.551     Expected Variance:   1.667

       Seed:    .674346863484
       Mean:    .041        Expected Mean:    0.000     Standard Dev.:   1.333
   Variance:   1.778     Expected Variance:   1.667
```

V: 10

Seed:	.125712189059				
Mean:	-.033	Expected Mean:	0.000	Standard Dev.:	1.111
Variance:	1.234	Expected Variance:	1.250		
Seed:	.723950998653				
Mean:	-.032	Expected Mean:	0.000	Standard Dev.:	1.149
Variance:	1.319	Expected Variance:	1.250		
Seed:	.842789866178				
Mean:	-.043	Expected Mean:	0.000	Standard Dev.:	1.079
Variance:	1.164	Expected Variance:	1.250		

V: 50

Seed:	.786277456806				
Mean:	-.016	Expected Mean:	0.000	Standard Dev.:	.996
Variance:	.993	Expected Variance:	1.042		
Seed:	.259341174646				
Mean:	-.020	Expected Mean:	0.000	Standard Dev.:	1.060
Variance:	1.123	Expected Variance:	1.042		
Seed:	.105927877294				
Mean:	.023	Expected Mean:	0.000	Standard Dev.:	1.051
Variance:	1.104	Expected Variance:	1.042		

At this point, you may select a particular data set which you can have printed out or saved on a mass storage device. You will be required to enter the following values: the size of the data set, the starting seed, and the degrees of freedom. For want of a better seed, PI is an excellent choice.

T DEVIATES:

Seed: .01745329252 V: 5.0000

I	X(I)	X(I+1)	X(I+2)	X(I+3)	X(I+4)
1	-.227298	-1.009491	.814428	-.193426	.685398
6	.510023	.042979	-.605420	-1.073209	-.045602
11	-.047114	-.636961	-1.055477	.615446	.171559
16	-.974860	-.579446	2.315553	-.742191	.090852
21	-1.471052	.110776	-.853836	-.596895	.673159

(RT1EXT)
Random Type I Extreme-Value Generator

(RT1EXT)
Random Type I Extreme-Value Generator

Description

This program generates sets of random Type I Extreme-Value deviates. The distribution function is defined as follows:

$$F(X) = \exp(-\exp[-Alpha*(X-Mu)])$$

File Name

"RT1EXT"

Calling Syntax

CALL Random_type1ext (Number,Alpha,Mu,X(*)).

Input Parameters

Number	number of random deviates desired.
Alpha,Mu	Type I parameters.

Output Parameters

X(*)	array of dimension (1:N) containing N Type I deviates.

Algorithm

1. Given parameters Alpha and Mu, generate a uniform deviate U.
2. Then the Type II deviate is equal to: $-\log[-\log(U)]/Alpha+Mu$.

Instructions

1. Insert the RANDOM NUMBER cartridge with the machine turned on.
2. a. Type: LOAD "RT1EXT",10
   b. Press: EXECUTE
3. The title "RANDOM TYPE I EXTREME-VALUE DEVIATES" is printed along with some introductory remarks.
4. When "ENTER VALUES FOR THE SIZE OF THE SET, SEED, Alpha, Mu. E.G. 100,PI,10,.8" is displayed:

   a. Enter values for the size of the set, the starting seed, and the Type I parameters Alpha and Mu.

   b. Press: CONT

5. After the data set has been created, the prompt: "WOULD YOU LIKE A PRINTOUT OF THE DATA? (Y/N)" is displayed:

   a. Enter Y if a printout is desired.

   b. Press: CONT

   c. Go to 6.

   or

   a. Enter N if a printout is not desired.

   b. Press: CONT

   c. Go to 8.

6. When "ENTER THE SELECT CODE OF THE PRINTER." is displayed:

   a. Enter the select code of the printer.

   b. Press: CONT

7. When "ENTER THE BUS ADDRESS OF THE PRINTER." is displayed:

   a. Enter the bus address of the printer.

   b. Press: CONT

8. When "WOULD YOU LIKE TO SAVE THE DATA SET? (Y/N)" is displayed:

   a. Enter Y if you would like it saved.

   b. Press: CONT

   c. Go to 9.

   or

   a. Enter N if you would not like it saved.

   b. Press: CONT

   c. At this point, the program terminates.

9. When "ENTER FILE NAME. FOR EXAMPLE, File:T14 OR DATA:F8" is displayed:

   a. Enter the desired file name.

   b. Press: CONT

   c. The data set is saved on your mass storage device as a vector and the program ends.

RANDOM TYPE I EXTREME-VALUE DEVIATES

This program generates sets of Type I extreme-value deviates. The distribution function is: F(X) = EXP(-EXP[-Alpha*(X-Mu)]).

In this program, you may select a particular data set which you can have printed out or saved on a mass storage device. You will be required to enter the following values: the size of the data set, the starting seed, and the parameters Alpha and Mu. For want of a better seed, PI is an excellent choice!

TYPE I EXTREME-VALUE DEVIATES:

Seed: .017453292520 Alpha: 10.000 Mu: .800

I	X(I)	X(I+1)	X(I+2)	X(I+3)	X(I+4)
1	.785932	.713688	1.026475	.796178	.948806
6	.932034	.846248	.673623	.716250	.831092
11	.831019	.713946	.597968	.927105	1.063444
16	1.080172	.735676	.927538	.868322	.713583
21	.810417	.921067	.681207	.857064	.750184

(RT2EXT)
Random Type II
Extreme-Value Generator

(RT2EXT)
Random Type II Extreme-Value Generator

Description

This program generates sets of random Type II Extreme-Value deviates. The distribution function is defined as follows:

F(X) = exp[−(V/X)∧K]

File Name

'RT2EXT''

Calling Syntax

CALL Random_type2ext (Number,V,K,X(*))

Input Parameters

Number	number of random deviates desired.
V,K	Type II parameters.

Output Parameters

X(*)	array of dimension (1:N) containing N Type II deviates.

Algorithm

1. Given parameters V and K, generate a uniform deviate U.
2. Then the Type II deviate is equal to: V*[−log(U)]∧(−1/K).

Instructions

1. Insert the RANDOM NUMBER cartridge with the machine turned on.
2. a. Type: LOAD "RT2EXT",10
   b. Press: EXECUTE
3. The title "RANDOM TYPE II EXTREME-VALUE DEVIATES" is printed along with some introductory remarks.
4. When "ENTER VALUES FOR THE SIZE OF THE SET, SEED, V, K. E.G. 100, PI,10,.8" is displayed:

   a. Enter values for the size of the set, the starting seed, and the Type II parameters V and K.
   b. Press: CONT

5. After the data set has been created, the prompt: "WOULD YOU LIKE A PRINTOUT OF THE DATA? (Y/N)" is displayed:

   a. Enter Y if a printout is desired.

   b. Press: CONT

   c. Go to 6.

   or

   a. Enter N if a printout is not desired.

   b. Press: CONT

   c. Go to 8.

6. When "ENTER THE SELECT CODE OF THE PRINTER." is displayed:

   a. Enter the select code of the printer.

   b. Press: CONT

7. When "ENTER THE BUS ADDRESS OF THE PRINTER." is displayed:

   a. Enter the bus address of the printer.

   b. Press: CONT

8. When "WOULD YOU LIKE TO SAVE THE DATA SET? (Y/N)" is displayed:

   a. Enter Y if you would like it saved.

   b. Press: CONT

   c. Go to 9.

   or

   a. Enter N if you would not like it saved.

   b. Press: CONT

   c. At this point, the program terminates.

9. When "ENTER FILE NAME. FOR EXAMPLE, File:T14 OR DATA:F8" is displayed:

   a. Enter the desired file name.

   b. Press: CONT

   c. The data set is saved on your mass storage device as a vector and the program ends.

RANDOM TYPE II EXTREME-VALUE DEVIATES

This program generates sets of Type II extreme-value deviates. The distribution function is: F(X) = exp[-(V/X)^K].

In this program, you may select a particular data set which you can have printed out or saved on a mass storage device. You will be required to enter the following values: the size of the data set, the starting seed, and the parameters V AND K. For want of a better seed, PI is an excellent choice!

TYPE II EXTREME-VALUE DEVIATES:

Seed: .01745329252 V: 10.000 K: .900

I	X(I)	X(I+1)	X(I+2)	X(I+3)	X(I+4)
1	8.387473	3.399702	169.612721	9.533464	64.242076
6	52.091762	17.826373	2.060339	3.510349	14.749902
11	14.736392	3.410663	.800267	48.979000	269.248818
16	331.868801	4.475137	49.244942	23.490015	3.395254
21	11.390763	45.418888	2.265232	20.407208	5.364942

(RUNIF)
Uniform Random Number Generator

(RUNIF)
Uniform Random Number Generator

Description

This program generates sets of uniform random numbers using the generator IRND.

File Name

"RUNIF"

Calling Syntax

CALL Random_uniform (N,X(*))

Input Parameters

N	number of random deviates desired.

Output Parameters

X(*)	array of dimension (1:N) containing N uniformly generated random numbers on the range [0,1).

Algorithm

See Appendix II.

Instructions

1. Insert the RANDOM NUMBER cartridge with the machine turned on.
2. a. Type: LOAD "RUNIF",10
   b. Press: EXECUTE
3. The title "UNIFORM RANDOM NUMBER GENERATOR" is printed along with options available to you in the program.

4. When "ENTER YOUR CHOICE. [EITHER 1 OR 2]" is displayed:

   a. Enter 1 if you want to directly generate a set of deviates.

   b. Press: CONT

   c. Go to 8.

   or

   a. Enter 2 if you would like to check through some randomly generated examples using a standard Chi-square test.

   b. Press: CONT

   c. Go to 5.

5. Default values are supplied for the size of the sets of deviates, and number of categories to be used in the Chi-square test.

   a. If the default values are satisfactory, simply press: CONT

   or

   a. Change the values as desired.

   b. Press: CONT

6. Three sets of deviates with different starting seeds are produced and a Chi-square test is performed for each data set. The starting seed, the Chi-square statistic and the right-tailed probability will be printed.

7. When "WOULD YOU LIKE TO CONSIDER A PARTICULAR DATA SET? (Y/N)" is displayed:

   a. Enter Y if you would like to generate a particular set to be printed out or saved on a mass storage device.

   b. Press: CONT

   or

   a. Enter N if no particular set is desired.

   b. Press: CONT

   c. At this point, the program is terminated.

8. When "ENTER VALUES FOR THE SIZE OF THE SET, SEED. E.G. 100, PI" is displayed:

   a. Enter values for the size of the set, the starting seed, the mean of the distribution.

   b. Press: CONT

9. After the data set has been created, the prompt: "WOULD YOU LIKE A PRINTOUT OF THE DATA? (Y/N)" is displayed:

   a. Enter Y if a printout is desired.
   b. Press: CONT
   c. Go to 10.

   or

   a. Enter N if a printout is not desired.
   b. Press: CONT
   c. Go to 12.

10. When "ENTER THE SELECT CODE OF THE PRINTER." is displayed:

    a. Enter the select code of the printer.
    b. Press: CONT

11. When "ENTER THE BUS ADDRESS OF THE PRINTER." is displayed:

    a. Enter the bus address of the printer.
    b. Press: CONT

12. When "WOULD YOU LIKE TO SAVE THE DATA SET? (Y/N)" is displayed:

    a. Enter Y if you would like it saved.
    b. Press: CONT
    c. Go to 13.

    or

    a. Enter N if you would not like it saved.
    b. Press: CONT
    c. At this point, the program terminates.

13. When "ENTER FILE NAME. FOR EXAMPLE, File:T14 OR DATA:F8" is displayed:

    a. Enter the desired file name.
    b. Press: CONT
    c. The data set is saved on your mass storage device as a vector and the program ends.

UNIFORM RANDOM NUMBER GENERATOR

This program generates sets of uniformly distributed random numbers in the range (0,1) using the generator IRND. The program may be used in the following ways:

1. Directly generate a set of deviates to be printed or saved on a mass storage device.

2. Check through some randomly generated tests in order to get a feel for the quality of the deviates produced. You would then have the option to create your own data set.

A series of Chi-square tests will be run on the generator using different number of observations. You will be required to enter values for the number of observations and the number of categories to be used in the Chi-square tests. Default values are provided for each input.

```
NUMBERS OF OBSERVATIONS: 1000
NUMBER OF CATEGORIES: 100
```

The resulting Chi-square statistic and the corresponding right-tailed probability will be printed for each test.

```
# OF OBSERVATIONS:  1000
     Seed: .842190093254     V:    82.2     Prob (X>V): .889
     Seed: .281868427612     V:   110.8     Prob (X>V): .196
     Seed: .051347621758     V:    88.6     Prob (X>V): .764
```

At this point, you may select a particular data set which you can have printed out or saved on a mass storage device. You will be required to enter the following values: the total number of observations and the starting seed. For want of a better seed, PI/180 is an excellent choice!

UNIFORM RANDOM DEVIATES:

Seed: .017453292520

I	X(I)	X(I+1)	X(I+2)	X(I+3)	X(I+4)
1	.216304	.093430	.901355	.353822	.797869
6	.765638	.532739	.029050	.099204	.480575
11	.480317	.094002	.000531	.755377	.930755
16	.941101	.149175	.756294	.603512	.093198
21	.406136	.742304	.037618	.568268	.192879

(RWEIBU)
Random Integers Generated From a Weibull Distribution

(RWEIBU)
Random Integers Generated From a Weibull Distribution

Description

This subprogram generates a set of Weibull deviates.

File Name

"RWEIBU"

Calling Syntax

CALL Random_weibull (N,Alpha,Beta,X(*))

Input Parameters

N	number of random deviates desired.
Alpha, Beta	Weibull parameters.

Output Parameters

X(*)	array of dimension (1:N) containing deviates randomly generated with the given Weibull distribution.

Reference

1. Wheeler, R.E., "Random Variable Generators", SIMULETTER, Vol. IV, April 1973, p. 22.

Instructions

1. Insert the RANDOM NUMBER cartridge with the machine turned on.
2. a. Type: LOAD "RWEIBU",10
   b. Press: EXECUTE
3. The title "RANDOM WEIBULL DEVIATES" is printed along with options available to you in the program.

4. When "ENTER YOUR CHOICE. [EITHER 1 OR 2]" is displayed:

   a. Enter 1 if you want to directly generate a set of deviates.
   b. Press: CONT
   c. Go to 8.

   or

   a. Enter 2 if you would like to check through some randomly generated examples.
   b. Press: CONT
   c. Go to 5.

5. Default values are supplied for the size of the sets of deviates, and for the parameters.

   a. If the default values are satisfactory, simply press: CONT

   or

   a. Change the values as desired.
   b. Press: CONT

6. One set of deviates with a different starting seed is produced for each set of parameters. After each data set is generated, the starting seed, the parameters, and the mean and variance of the set are printed as well as the expected mean and variance.
7. When "WOULD YOU LIKE TO CONSIDER A PARTICULAR DATA SET? (Y/N)" is displayed:

   a. Enter Y if you would like to generate a particular set to be printed out or saved on a mass storage device.
   b. Press: CONT
   c. Go to 8.

   or

   a. Enter N if no particular set is desired.
   b. Press: CONT
   c. At this point, the program is terminated.

8. When "ENTER VALUES FOR THE SIZE OF THE SET, SEED, Alpha, Beta. E.G., 100,PI,3.5" is displayed:

   a. Enter values for the size of the set, the starting seed, and the appropriate parameters.
   b. Press: CONT

9. After the data set has been created, the prompt: "WOULD YOU LIKE A PRINTOUT OF THE DATA? (Y/N)" will be displayed:

   a. Enter Y if a printout is desired.

   b. Press: CONT

   c. Go to 10.

   or

   a. Enter N if a printout is not desired.

   b. Press: CONT

   c. Go to 12.

10. When "ENTER THE SELECT CODE OF THE PRINTER." is displayed:

    a. Enter the select code of the printer.

    b. Press: CONT

11. When "ENTER THE BUS ADDRESS OF THE PRINTER." is displayed:

    a. Enter the bus address of the printer.

    b. Press: CONT

    c. The data set is printed on the appropriate device.

12. When "WOULD YOU LIKE TO SAVE YOUR DATA SET? (Y/N)" is displayed:

    a. Enter Y if you would like it saved.

    b. Press: CONT

    c. Go to 13.

    or

    a. Enter N if you would not like it saved.

    b. Press: CONT

    c. At this point, the program terminates.

13. When "ENTER FILE NAME. FOR EXAMPLE, File:T14 OR DATA:F8" is displayed:

    a. Enter the desired file name.

    b. Press: CONT

    c. The data set is saved on your mass storage device as a vector and the program ends.

RANDOM WEIBULL DEVIATES

This program generates sets of Weibull (Alpha,Beta) random deviates from the distribution:

F(X) = 1-EXP[-X^(Beta)/Alpha].

You may use the program in two ways:

1. Directly generate a set of deviates to be printed or saved on a mass storage device.

2. Check through some randomly generated tests in order to get a feel for the quality of the deviates produced. You would then have the option to create your own data set.

This program generates sets of Weibull(Alpha,Beta) random deviates. It also compares the resulting data with the theoretical expectations. In particular, given parameters Alpha and Beta, the mean and variance of each set of random numbers is calculated.

The program is set up using the following default values:

1. 100 deviates will be generated for each set of Weibull parameters.

2. Values for Alpha and Beta, the Weibull parameters, are set at 2,5,10 and .5,1.5,2 respectively.

3. Results printed are:
   - mean, expected mean, and standard deviation for each set.
   - variance and expected variance for each set.

Default values may be changed from the keyboard as they come up.

```
# OF RANDOM DEVIATES: 1000
ALPHA PARAMETERS: 2, 5, 10
BETA PARAMETERS: .5, 1.5, 2


Number:  1000

      Seed:      .082190093205        Alpha:   2.00              Beta:   .50
      Mean:     7.942       Expected Mean:     8.000   Standard Dev.: 16.388
  Variance:   268.567   Expected Variance:   320.000

      Seed:      .121868385812        Alpha:   2.00              Beta:  1.50
      Mean:     1.464       Expected Mean:     1.433   Standard Dev.:  1.019
  Variance:     1.039   Expected Variance:      .947

      Seed:      .491312467983        Alpha:   2.00              Beta:  2.00
      Mean:     1.222       Expected Mean:     1.253   Standard Dev.:   .654
  Variance:      .428   Expected Variance:      .429
```

```
     Seed:       .193785573561        Alpha:   5.00              Beta:    .50
     Mean:     50.047       Expected Mean:    50.000   Standard Dev.:106.463
 Variance: 11334.450   Expected Variance: 12500.000

     Seed:       .973667364881        Alpha:   5.00              Beta:   1.50
     Mean:      2.563       Expected Mean:     2.640   Standard Dev.:   1.755
 Variance:      3.079   Expected Variance:     3.212
```

```
     Seed:       .854253863553        Alpha:   5.00              Beta:   2.00
     Mean:      2.004       Expected Mean:     1.982   Standard Dev.:   1.100
 Variance:      1.210   Expected Variance:     1.073

     Seed:       .427499247062        Alpha:  10.00              Beta:    .50
     Mean:    198.173       Expected Mean:   200.000   Standard Dev.:427.305
 Variance:182589.804   Expected Variance:200000.000

     Seed:       .526866779278        Alpha:  10.00              Beta:   1.50
     Mean:      4.241       Expected Mean:     4.190   Standard Dev.:   2.879
 Variance:      8.290   Expected Variance:     8.094

     Seed:       .094961373904        Alpha:  10.00              Beta:   2.00
     Mean:      2.776       Expected Mean:     2.802   Standard Dev.:   1.533
 Variance:      2.351   Expected Variance:     2.146
```

At this point, you may select a particular data set which you can have printed out or saved on a mass storage device. You will be required to enter the following values: the size of the data set, the starting seed, and the two Weibull parameters. For want of a better seed, PI is an excellent choice!

WEIBULL DEVIATES:

Seed: .017453292520   Alpha: 5.0000   Beta: 1.5000

I	X(I)	X(I+1)	X(I+2)	X(I+3)	X(I+4)
1	1.534687	.621902	5.118788	1.688019	3.998067
6	3.747455	2.436985	.279040	.648624	2.205407
11	2.204292	.624564	.019178	3.673297	5.627718
16	5.852853	.867328	3.679823	2.776147	.620821
21	1.893490	3.582183	.332489	2.603049	1.047058

Tests for Randomness in BASIC

Tests for Randomness in BASIC

A standard set of Statistical tests for randomness is provided. These tests are designed as independent subprograms with optional drivers. These driver programs have been set up to test the binary random number generator IRND for randomness. The aim here is twofold: i) to actually allow you to check the randomness of IRND; and ii) to show you how a typical test might be set up.

(TCHISQ)
Chi-square Test

(TCHISQ)
Chi-square Test

Description

This subprogram performs a Chi-Square test on a set of observations placed in a set of categories with given probabilities.

File Name

"TCHISQ"

Calling Syntax

Call Chi_sq_test (N,Cats,Prob(*),Obs(*),V,P)

Input Parameters

N	number of observations. This should be at least 5 *Cats, but preferably much larger, for a valid test.
Cats	number of categories.
Prob(*)	array of dimension (1:Cats) containing the probabilities of any event occurring in a particular category. Care must be taken to insure that no probability value is too small.
Obs(*)	array of dimension (1:Cats) containing the number of observations occurring in each category.

Output Parameters

V	Chi-square statistic. V is expected to have the Chi-square distribution with (Cats-1) degrees of freedom.
P	right-tailed probability; Prob (X>V).

Special Considerations

1. The Chi-square method can only be used with sets of independent observations.
2. The proper choice of N is somewhat obscure. Large values of N will tend to smooth out 'locally' nonrandom behavior, that is, blocks of numbers with a strong bias followed by blocks of numbers with the opposite bias. But, N should be large enough so that each of the expected values N*Prob>=5 for the probability associated with each category. Preferably, N should be taken much larger than this. So, the method should probably be used with a number of different values of N.
3. From the Chi-square formula, we can see that a very small probability value would severely influence the Chi-square statistic. Hence, it is suggested that categories with very small probabilities be grouped together into one larger category.

Algorithm

A fairly large number, N, of independent observations is made. We count the number of observations falling into each of K categories, and compute the quantity

$$V = (1/N) * \sum_{i=1}^{K} ((observed(I)\wedge 2)/Prob(I)) - N$$

In the associated driver program, the right-tailed probability P(X>V) is then calculated using (K-1) as the number of degrees of freedom.

Reference

1. Knuth, Donald E., The Art of Computer Programming, Volume 2 Seminumerical Algorithms. Reading, Mass.: Addison-Wesley, 1969, p. 35-40.

Instructions

1. Insert the GOODNESS-OF-FIT cartridge with the machine turned on.
2. a. Type: LOAD "TCHISQ",10
   b. Press: EXECUTE
3. The title "CHI-SQUARE TEST" is printed along with an explanation of the test. The driver program is set up to test the uniform random number generator: IRND. Default values are provided for each input.
4. When "NUMBERS OF OBSERVATIONS?" is displayed:
   a. Enter the number of observations desired for each set size. Three independent tests are run on each sized set.
   b. Press: CONT
5. When "NUMBER OF CATEGORIES?" is displayed:
   a. Enter the number of categories into which the data set is to be partitioned. For example, to check the randomness of the first digit, 10 categories would be sufficient; to check the first two digits, 100 categories would suffice.
   b. Press: CONT
6. The resulting Chi-square statistic and the corresponding right-tailed probability is printed for each set.

CHI-SQUARE TEST

This program performs a Chi-square goodness of fit test on a given set of data. The random number generator IRND will be tested using different numbers of observations.

You will be required to enter the values for the number of observations to be used and for the number of corresponding categories. Three tests will be run at each level. Default values are provided for each input.

First enter the number of observations for each set. This has been set up as: 1000, 5000, and 10000. You may edit these values from the keyboard. Then press 'CONT'.

```
NUMBERS OF OBSERVATIONS: 1000, 5000, 10000
NUMBER OF CATEGORIES: 100
```

The resulting Chi-square statistic and the corresponding right-tailed probability will be printed for each test.

```
# OF OBSERVATIONS:  1000
     Seed: .432190093254     V:    95.4     Prob (X>V): .584
     Seed: .471868427612     V:   113.4     Prob (X>V): .153
     Seed: .841347620384     V:    89.6     Prob (X>V): .740

# OF OBSERVATIONS:  5000
     Seed: .573348741980     V:   108.2     Prob (X>V): .248
     Seed: .196292004613     V:   100.4     Prob (X>V): .441
     Seed: .671575879668     V:   113.7     Prob (X>V): .149

# OF OBSERVATIONS:  10000
     Seed: .795314801600     V:   103.6     Prob (X>V): .357
     Seed: .859748145692     V:   102.9     Prob (X>V): .374
     Seed: .048190527910     V:    82.0     Prob (X>V): .891
```

(TKS)
Kolmogorov-Smirnov Test

(TKS)
Kolmogorov-Smirnov Test

Description

Given a continuous distribution function F(X), this subprogram calculates the standard Kolmogorov-Smirnov statistics of maximum deviation.

File Name

"TKS"

Calling Syntax

Call K_s_test (N,Knp,Knn)

Input Parameters

N	number of observations

The distribution function F(X) must be provided as an in line function to the subprogram.

Output Parameters

Knp	positive K-S statistic.
Knn	negative K-S statistic.

Algorithm

Given a distribution function F(x)=probability that (X<=x) for a random variable X, the statistics Knp (Kn positive) and Knn (Kn negative) can be obtained as follows:

1. Obtain the observations x1, x2, ..., xn.
2. Sort the observations: x1<=x2<=...<=xn.
3. Knp = SQR(n) * maximum of [j/n-F(xj)] where 1<=j<=n.
   Knn = SQR(n) * maximum of [F(xj)−(j−1)/n] where 1<=j<=n.

Special Considerations

1. The method used in the driver program of using several tests for moderately sized N, then combining the observations later in another K-S test, tends to detect both local and global nonrandom behavior.

Reference

1. Knuth, Donald E., The Art of Computer Programming, Volume 2 Seminumerical Algorithms. Reading, Mass.: Addison-Wesley, 1969, p. 41-48.

Instructions

1. Insert the GOODNESS-OF-FIT cartridge with the machine turned on.
2. a. Type: LOAD "TKS",10
   b. Press: EXECUTE
3. The title "KOLMOGOROV-SMIRNOV TEST" is printed along with an explanation of the test. The driver program is set up to test the uniform random number generator: IRND. Default values are provided for each input.
4. When "# OF SETS TO BE GENERATED?" is displayed:
   a. Enter the number of sets desired.
   b. Press: CONT
5. The resulting individual K-S statistics are printed after each set of data is produced. The mean and standard deviation of the set of K-S statistics is then calculated. Finally, a K-S test is then applied to the above individual statistics.

KOLMOGOROV-SMIRNOV TEST

This program uses the Kolmogorov-Smirnov Goodness-of-Fit test to evaluate the randomness of the uniform generator IRND. The test is set up as follows:

1. Sets of 1000 uniform deviates are generated.
2. For each set, the K-S statistics are calculated.
3. The means and standard deviations of the set of K-S statistics are also calculated.
4. The K-S test is then applied to the above K-S statistics. For large N, say N=1000, the distribution of the K-S statistics is closely approximated by:

F(X) = 1-EXP(-2*X*X)   for X>=0.

This method of using several tests for moderately sized N, then combining the observations later in another K-S test, will tend to detect both local and global nonrandom behavior.

OF SETS TO BE GENERATED: 10

INDIVIDUAL K-S STATISTICS:

# 1	Seed:	.872190093254	Kp(1000)=	.7094	Kn(1000)=	.5041
# 2	Seed:	.511868427612	Kp(1000)=	.2272	Kn(1000)=	.9500
# 3	Seed:	.481347620384	Kp(1000)=	.9574	Kn(1000)=	.2105
# 4	Seed:	.813348741980	Kp(1000)=	.8219	Kn(1000)=	.5993
# 5	Seed:	.026292004601	Kp(1000)=	.4776	Kn(1000)=	.5067
# 6	Seed:	.111575869768	Kp(1000)=	.8574	Kn(1000)=	.2157
# 7	Seed:	.835306474800	Kp(1000)=	.9030	Kn(1000)=	.1758
# 8	Seed:	.492745306887	Kp(1000)=	.3526	Kn(1000)=	.7170
# 9	Seed:	.398803091313	Kp(1000)=	1.3903	Kn(1000)=	.2761
#10	Seed:	.393399794989	Kp(1000)=	.4465	Kn(1000)=	.5556

MEAN & SD OF INDIVIDUAL TESTS:

Kp(1000):	Mean=	.7143	Sd=	.3463
Kn(1000):	Mean=	.4711	Sd=	.2526

COMBINED K-S STATISTICS:

Kp(10):	Kp=	.1894	Kn=	.7621
Kn(10):	Kp=	.9092	Kn=	.1896

(TMAXT)
Maximum of T Test

(TMAXT)
Maximum of T Test

Description

This routine generates groups of uniform random numbers, finds the maximum of each group and then applies the Kolmogorov-Smirnov test to the resulting set of numbers.

File Name

"TMAXT"

Calling Syntax

CALL Max_of_t (N,T,Knp,Knn)

Input Parameters

N	number of groups to be tested.
T	size of each group.

Output Parameters

Knp	positive Kolmogorov-Smirnov statistic.
Knn	negative Kolmogorov-Smirnov statistic.

Algorithm

For 0<=j<n, let Vj = max(Utj, Utj+1, ..., Utj+t−1) where the U's are uniformly distributed random numbers.

Now apply the Kolmogorov-Smirnov test to the sequence V0, V1, ..., Vn-1, with the distribution function F(x)=X∧t, (0<=X<=1).

Reference

1. Knuth, Donald E., The Art of Computer Programming, Vol. II, Seminumerical Algorithms, Reading, Mass.: Addison-Wesley, 1969, p. 64.

Instructions

1. Insert the GOODNESS-OF-FIT cartridge with the machine turned on.
2. a. Type: LOAD "TMAXT",10
   b. Press: EXECUTE

3. The title "MAXIMUM OF T TEST" is printed along with an explanation of the test. The driver program is set up to test the uniform random number generator: IRND. Default values are provided for each input.
4. When "# OF GROUPS?" is displayed:

   a. Enter the number of groups desired. This should be at least 200 for a reasonable test.

   b. Press: CONT

5. When "SIZE OF EACH GROUP?" is displayed:
   a. Enter the desired size of each group.
   b. Press: CONT
6. When "INITIAL SEED?" is displayed:

   a. Enter an initial seed. For want of a better value, PI/180 is an excellent choice.

   b. Press: CONT

7. The resulting K-S statistics are printed for each data set.

```
                         MAXIMUM-OF-T TEST

   In the Maximum of T test, we take groups of random numbers from the sequence
of numbers generated by IRND.  We then look at the maximum value in each of
these groups using the Kolmogorov-Smirnov test.  The distribution function used
is:     F(X) = X^T  where T is the number of elements in each group.

   You will be required to enter the number of groups you would like to test as
well as the size of each group.  The program will supply a reasonable default
value for each of these inputs.  Three tests will then be performed.


# OF GROUPS:   200
SIZE OF EACH GROUP:   5

   Seed:   .402190093254      Knp:      .4261      Knn:      .5414
   Seed:   .241968427612      Knp:      .9818      Knn:      .1992
   Seed:   .411347621744      Knp:      .3553      Knn:      .9431
```

(TPOKER)
Modified Poker Test

(TPOKER)
Modified Poker Test

Description

This subprogram calculates the number of distinct values in a given set of observations. A Chi-square test is then applied to the set of data.

File Name

"TPOKER"

Calling Syntax

CALL Poker_test (K,N,Digits,V,P)

Input Parameters

K	number of possible different digits in a set. The degrees of freedom is then (K-1). A reasonable number here is 5.
N	number of test sets to be used. N should be at least 5*(K-1), but perferably much larger, for a valid Chi-square test.
Digits	range on the allowed digits, [0,Digits-1]. 13 or 10 would be reasonable values here.

Output Parameters

V	Chi-square statistic. V is expected to have the Chi-square distribution with (K-1) degrees of freedom.
P	right-tailed probability; Prob (X>V).

Algorithm

In general, we look at n groups of k successive numbers. We count the number of k-tuples with r different values. For example, generate 1000 groups of 5 successive numbers, where the numbers range from 1 to 13. How many sets have all 5 numbers different? How many have 4 different? How many 3? 2? 1?

A Chi-square test is then made, using the probability

$$P(r) = d^*(d-1)^*\ldots^*(d-r+1)/(d\wedge k)^*S(k,r)$$

where d is the number of possible digits considered and S(k,r) is the standard Sterling number of k,r.

Reference

1. Knuth, Donald E., The Art of Computer Programming, Volume 2 Seminumerical Algorithms. Reading, Mass.: Addison-Wesley, 1969, p. 57-58.

Instructions

1. Insert the GOODNESS-OF-FIT cartridge with the machine turned on.
2. a. Type: LOAD "TPOKER",10
   b. Press: EXECUTE
3. The title "MODIFIED POKER TEST" is printed along with an explanation of the test. The driver program is set up to test the uniform random number generator: IRND. Default values are provided for each input.
4. You will be required to enter a starting and ending value for the number of groups desired, as well as the increment between values. At each value, three independent tests are run.
5. When "STARTING VALUE: # OF GROUPS?" is displayed:
   a. Enter the starting value for the number of groups desired.
   b. Press: CONT
6. When "FINAL VALUE: # OF GROUPS? is displayed:
   a. Enter the final value for the number of groups desired.
   b. Press: CONT
7. When "INCREMENT VALUE?" is displayed:
   a. Enter the increment value.
   b. Press: CONT
8. The number of possible digits has been set at 10 and the size of each hand has been set equal to 5.
9. The resulting Chi-square statistic and the corresponding right-tailed probability is printed for each set.

(TRUNS)
Runs Test

(TRUNS)
Runs Test

Description

This subprogram sets up N random numbers and calculates the number of ascending or descending runs in the sequence. A special Chi-square statistic is then produced.

File Name

"TRUNS"

Calling Syntax

CALL Runs-test (N,Direction,V,P)

Input Parameters

N	number of random deviates used. The value of N should be 4000 or more.
Direction	Direction= 1 => ascending run. Direction=−1 => descending run.

Output Parameters

V	Chi-square statistic. Since adjacent runs are not independent, a standard Chi-square test cannot be used here. A special test, with 6 degrees of freedom is used instead.
P	Right-tailed probability; Prob (X>V).

Algorithm

In this algorithm, we examine the length of monotone subsequences of an original sequence of random numbers; that is, segments which are increasing or decreasing.

1. Calculate the increasing (or decreasing) run lengths and count how many runs have length 1, 2, ..., 6 or greater.
2. Since adjacent runs are not independent, we cannot apply a standard Chi-square test to the above data. Instead, we calculate a special statistic V (see Ref. 1, p. 61) which should have the Chi-square distribution with six degrees of freedom, when N is large. The value of N should be at least 4000 for a valid test. This test may also be used for decreasing runs.

Reference

1. Knuth, Donald E., The Art of Computer Programming, Volume 2 Seminumerical Algorithms. Reading, Mass.: Addison-Wesley, 1969, p. 60-61.

Instructions

1. Insert the GOODNESS-OF-FIT cartridge with the machine turned on.
2. a. Type: LOAD "TRUNS",10
   b. Press: EXECUTE
3. The title "RUNS TEST" is printed along with an explanation of the test. The driver program is set up to test the uniform random number generator: IRND. Default values are provided for each input.
4. When "ENTER 1 FOR RUNS UP; -1 FOR RUNS DOWN." is displayed:

   a. Enter 1 for a runs up test.

   b. Press: CONT

   or

   a. Enter −1 for a runs down test.

   b. Press: CONT
5. When "STARTING VALUE: NUMBER OF OBSERVATIONS?" is displayed:

   a. Enter the starting value for the number of observations.

   b. Press: CONT
6. When "FINAL VALUE: NUMBER OF OBSERVATIONS?" is displayed:
   a. Enter the final value for the number of observations.
   b. Press: CONT
7. When "INCREMENT VALUE?" is displayed:
   a. Enter the increment value.
   b. Press: CONT
8. The resulting special Chi-square statistic and the corresponding right-tailed probability is printed for each set.

```
                         RUNS TEST

   This program tests the random number generator IRND for sequences of 'runs
up' and 'runs down'.  This means we examine the length of monotone subsequences
of the original sequence, that is, segments which are increasing or decreasing.

   Since a long run will tend to be followed by a short run, and vice versa,
adjacent runs are not independent.  Hence, we should not apply the standard
Chi-Square test to the sampled data.  Instead, a special statistic is generated
which has the Chi-Square distribution with six degrees of freedom, when the
number of samples is large, say, 4000, or more.  (See the user's manual for
further details.)
```

This program is set up to perform a series of runs tests. Simply enter the starting and ending values for the number of observations and the incremental value between tests. So, for example, a starting value of 4000, an ending value of 10000, and an increment of 1000, would generate tests on 4000 observations, 5000 observations,..., and 10000 observations. At each level, 3 tests will be run. Default values are provided for each input.

```
RUNS UP
STARTING VALUE: # OF OBSERVATIONS = 4000
FINAL VALUE: # OF OBSERVATIONS = 10000
INCREMENT VALUE =   1000

# of Observations:  4000
     Seed:  .723190093254     V:    2.9     Prob (X>V): .823
     Seed:  .202868427612     V:    7.8     Prob (X>V): .252
     Seed:  .612347621784     V:   14.7     Prob (X>V): .023 **

# of Observations:  5000
     Seed:  .994349919381     V:    7.4     Prob (X>V): .287
     Seed:  .838282198047     V:    4.8     Prob (X>V): .565
     Seed:  .995328558683     V:    1.6     Prob (X>V): .952

# of Observations:  6000
     Seed:  .071317852203     V:    5.4     Prob (X>V): .500
     Seed:  .978313702577     V:    6.4     Prob (X>V): .383
     Seed:  .761823866397     V:    5.6     Prob (X>V): .473

# of Observations:  7000
     Seed:  .693871639521     V:    7.0     Prob (X>V): .323
     Seed:  .546048836977     V:    3.2     Prob (X>V): .778
     Seed:  .227071896716     V:    8.6     Prob (X>V): .200

# of Observations:  8000
     Seed:  .967465138085     V:   11.0     Prob (X>V): .089 *
     Seed:  .638181130590     V:    2.7     Prob (X>V): .850
     Seed:  .710330825952     V:    6.1     Prob (X>V): .411

# of Observations:  9000
     Seed:  .388224625493     V:    6.8     Prob (X>V): .343
     Seed:  .496910039714     V:    7.4     Prob (X>V): .283
     Seed:  .901343399391     V:    2.5     Prob (X>V): .873

# of Observations:  10000
     Seed:  .029798886706     V:   14.9     Prob (X>V): .021 **
     Seed:  .060863719607     V:    2.9     Prob (X>V): .823
     Seed:  .186388189147     V:    9.7     Prob (X>V): .136
```

(TSERAL)
Serial Test

(TSERAL)
Serial Test

Description

This subprogram tests whether pairs of successive numbers are uniformly distributed in an independent manner.

File Name

"TSERAL"

Calling Syntax

CALL Serial_test (N,D,D_squared,V,P)

Input Parameters

N	number of uniform random numbers to be tested.
D	number of digits permitted. 5 or 10 is a reasonable number here.
D_squared	D * D; this must be passed as a parameter to allow for dynamic allocation of arrays.

Output Parameters

V	Chi-square statistic. V is expected to have the Chi-square distribution with (D*D−1) degrees of freedom.
P	right-tailed probability; Prob(X>V).

Algorithm

Given n =	total number of uniform random numbers.
d =	number of digits permitted; that is, the deviates created are used to create integers 1,2,..., d.
yj =	jth random integer.

Then for each pair of integers (q,r) with 0<=q,r<d count the number of times the pair

(y2j,y2j+1)=(q,r) occurs, for 0<=j<n.

Finally, apply the Chi-square test to these k=d*d equi-probable categories with probability 1/(d*d) in each case.

Special Considerations

1. The number of digits permitted may be chosen as any convenient number. But care must be taken since a valid Chi-square test should have n large compared to k; that is, n>5*d*d at least.

So, if

d = 10	then	n>500
d = 20	then	n>2000

etc.

2. This test may easily be adapted to triples, quadruples, etc., instead of pairs. But the value of d must be severely limited in order to avoid having too many categories. Frequently, in this case, less exact tests, such as the poker test or the maximum of t test are used instead.

Reference

1. Knuth, Donald E., The Art of Computer Programming, Volume 2 Seminumerical Algorithms. Reading, Mass.: Addison-Wesley, 1969, p. 55-56.

Instructions

1. Insert the GOODNESS-OF-FIT cartridge with the machine turned on.
2. a. Type LOAD "TSERAL",10
   b. Press: EXECUTE
3. The title "SERIAL TEST" is printed along with an explanation of the test. The driver program is set up to test the uniform random number generator: IRND. Default values are provided for each input.
4. You are required to enter a starting and ending value for the number of groups desired, as well as the increment between values. At each value, three independent tests are run.
5. When "STARTING VALUE: # OF GROUPS?" is displayed:
   a. Enter the starting value for the number of groups desired.
   b. Press: CONT
6. When "FINAL VALUE: # OF GROUPS?" is displayed:
   a. Enter the final value for the number of groups desired.
   b. Press: CONT
7. When "INCREMENT VALUE?" is displayed:
   a. Enter the increment value.
   b. Press: CONT

8. When "# OF DIGITS?" is displayed:

   a. Enter the number of digits allowed. For example, if you enter 10, the digits 1,2,...,10 is used. This also sets the degrees of freedom in the Chi-square test to digit*digit-1.

   b. Press: CONT

9. The resulting Chi-square statistic and the corresponding right-tailed probability is printed for each set.

```
                              SERIAL TEST

   The Serial Test checks that pairs of successive numbers are uniformly
distributed in an independent manner.  The Chi-square test statistic, as well
as the associated probability, are the resultant products.

   This driver program is set up to perform a number of test runs on the
uniform random number generator, IRND.  For example, we can allow 5 possible
digits, and perform the test with runs ranging in size from 200 to 1000, taking
3 cases at each size.  To simplify the required data input, default values will
be provided.


   Tests of different sizes will be run.  To automate the input, you will
be asked the starting size value, the increment, and the ending size value.
Again, these will default to appropriate values.

STARTING SIZE VALUE: 200
INCREMENTAL VALUE: 100
FINAL VALUE: 1000

   In this test, we count the number of times a pair of random digits occurs.
You will be required to enter the number of allowed digits.  Care must be
taken since a valid chi-square test should have a large number of runs compared
to the number of permitted digits.

# OF DIGITS: 5        DEGREES OF FREEDOM FOR CHI-SQUARE TEST:  24


SIZE OF TEST:  200
     Seed:  .252190093254      V:  28.8      Prob (X>V): .230
     Seed:  .091868426731      V:  31.3      Prob (X>V): .147
     Seed:  .261346880884      V:  31.0      Prob (X>V): .154


SIZE OF TEST:  300
     Seed:  .792726823659      V:  22.0      Prob (X>V): .579
     Seed:  .683258696977      V:  23.0      Prob (X>V): .520
     Seed:  .620564156702      V:  19.8      Prob (X>V): .706
```

```
SIZE OF TEST:  400
      Seed:  .894455787660     V:  24.4     Prob (X>V): .440
      Seed:  .237317420917     V:  24.3     Prob (X>V): .447
      Seed:  .583950991105     V:  24.9     Prob (X>V): .413

SIZE OF TEST:  500
      Seed:  .102783518078     V:  29.8     Prob (X>V): .191
      Seed:  .440938703522     V:  16.0     Prob (X>V): .888
      Seed:  .829449660922     V:  21.1     Prob (X>V): .633

SIZE OF TEST:  600
      Seed:  .567164834301     V:  22.8     Prob (X>V): .535
      Seed:  .985625646380     V:  25.9     Prob (X>V): .357
      Seed:  .911168605043     V:  13.3     Prob (X>V): .962

SIZE OF TEST:  700
      Seed:  .292796839889     V:  28.3     Prob (X>V): .248
      Seed:  .242142346608     V:  30.9     Prob (X>V): .156



      Seed:  .641713497280     V:  21.7     Prob (X>V): .596

SIZE OF TEST:  800
      Seed:  .681051211991     V:  25.1     Prob (X>V): .399
      Seed:  .764069283385     V:  32.0     Prob (X>V): .127
      Seed:  .582267327809     V:  19.6     Prob (X>V): .721

SIZE OF TEST:  900
      Seed:  .686822688552     V:  21.5     Prob (X>V): .609
      Seed:  .617881072057     V:  23.9     Prob (X>V): .465
      Seed:  .637981601351     V:  26.0     Prob (X>V): .353

SIZE OF TEST:  1000
      Seed:  .542526736866     V:  22.2     Prob (X>V): .570
      Seed:  .264985703975     V:  18.7     Prob (X>V): .770
      Seed:  .852977042885     V:  27.8     Prob (X>V): .271
```

(SPCTRL)
Spectral Test

(SPCTRL)
Spectral Test

Description

This test is used in theoretically determining the value of coefficient A, given the word size of the computer, M, in the linear congruential model described in Appendix II. The value of A is crucial in setting up a good uniform random number generator. This is by far the most powerful test currently available on any sized machine. It tends to measure the statistical independence of adjacent n-tuples of numbers and is generally applied for N=2,3,4 and perhaps a few higher values of N.

File Name

"SPCTRL"

Calling Syntax

CALL Spectral (A,M,N,Info,Q,V,Cn)

Input Parameters

A	the multiplier to be tested. It is essential that the linear congruential sequence be of maximal period.
M	modulus used in the model; in our case, M=10∧12, the word size of the computer. This cannot be changed if the binary random number generator IRND is being used.
N	size of n-tuple to be measured. This test is generally applied for N=2,3,4 and perhaps a few higher values of N.
Info	intermediate information on program execution each time a particular section of code has been entered as well as total number of iterations required for convergence can be printed out at the user's option: Info=1 => print out intermediate information. Info=0 => do not print out the information.

Output Parameters

Q	V∧2.
V	smallest nonzero wave number in the spectrum.
Cn	$= \dfrac{PI\wedge(N/2)*V\wedge N}{(N/2)!*M}$

Special Considerations

1. Since BASIC string routines are used to perform the multi-precision arithmetic, this program is very slow.

2. The subprogram allows at most 12 digits for A and M. If larger numbers are desired, some parameters must be changed to strings before entering the routine.

Change:
```
SUB Spectral (A,M,N,Info,Q,V,Cn)
DIM -------
Coef$=VAL$(A)
CALL Clean-up (Coef$)
Base$=VAL$(M)
CALL Clean-up (Base$)
.
.
.
```

To:
```
SUB Spectral (Coef$,Base$,N,Info,Q,V,Cn)
```

The reason for this is that with the 9845 processor, a simple variable can hold at most 12 digits. All extra digits are lost.

3. As suggested in the literature, the driver has been set up for N=2,3,4,5,6.
4. The multi-precision arithmetic routines are set up as independent subprograms so that the user may apply them to other contexts as well. Presently, each of these routines allows for up to 90 digits of accuracy. This can be increased simply by changing the DIM statements at the beginning of each routine.

Reference

1. Knuth, Donald E., The Art of Computer Programming, Vol. II, Seminumerical Algorithms. Reading, Mass.: Addison-Wesley, 1969, p. 69-100.

Instructions

1. Insert the GOODNESS-OF-FIT cartridge with the machine turned on.
2. a. Type: LOAD "SPCTRL",10
   b. Press: EXECUTE
3. When the title "SPECTRAL TEST" is printed and "HOW MANY PAIRS OF NUMBERS WOULD YOU LIKE TO CHECK?" is displayed:

   a. Enter the desired number of pairs.

   b. Press: CONT

NOTE:
This test is quite slow. It is not unusual for it to run for a couple of hours with one pair.

---

4. When "A(I)?" and "M(I)?" are displayed:
   a. Enter the desired A coefficient and the M word size.
   b. Press: CONT
   c. Repeat this step until all pairs have been entered.
5. When the pairs of numbers have been printed and "CHANGES?" (Y/N)" is displayed:

   a. Enter Y if changes are desired.

   b. Press: CONT

   c. Go to 6.

   or

   a. Enter N if no changes are desired.

   b. Press:CONT

   c. Go to 8.

6. When "ENTER THE NUMBER OF THE PAIR TO BE CHANGED." is displayed:

   a. Enter the appropriate number.

   b. Press: CONT

7. When "A(I)?" and "M(I)?" are displayed:

   a. Enter the corrected values.

   b. Press: CONT

   c. Go to 5.

8. When "WOULD YOU LIKE THE INTERMEDIATE STEPS LISTED AS THEY ARE EXECUTED? (Y/N)" is displayed:

   a. Enter Y if the intermediate steps are desired. This means that each time a particular section of code is entered, the label of that section is printed. Also, the total number of required iterations is output.

   b. Press: CONT

   or

   a. Enter N if the listing is not desired.

   b. Press: CONT

9. The program has been set up with n-tuples of size 2, 3, 4, 5 and 6. For each of these values, the quantity Cn is calculated. Large values of Cn correspond to randomness, small values correspond to nonrandomness. Knuth suggests that the multiplier A passes the spectral test if the Cn values are all greater than or equal to 0.1, and it passes the test with flying colors if all are greater than or equal to 1.

```
                    SPECTRAL TEST

      A( 1):   314159262221      M( 1): 1000000000000
      A( 2):     3954654621      M( 2): 1000000000000

A:  314159262221    M: 1000000000000    N:  2     =>  Cn: 2.7079

A:  314159262221    M: 1000000000000    N:  3     =>  Cn: 2.7397

A:  314159262221    M: 1000000000000    N:  4     =>  Cn: 1.4861

A:  314159262221    M: 1000000000000    N:  5     =>  Cn: 2.1204

A:  314159262221    M: 1000000000000    N:  6     =>  Cn: 1.9664

A:    3954654621    M: 1000000000000    N:  2     =>  Cn:  .5075

A:    3954654621    M: 1000000000000    N:  3     =>  Cn:  .5234

A:    3954654621    M: 1000000000000    N:  4     =>  Cn:  .1800

A:    3954654621    M: 1000000000000    N:  5     =>  Cn:  .6891

A:    3954654621    M: 1000000000000    N:  6     =>  Cn:  .3263
```

Elementary Sampling Techniques

Elementary Sampling Techniques in BASIC

This section provides some elementary sampling and shuffling techniques. Independent subprograms with optional driver routines are provided.

(SSEL)
Selection Sampling

(SSEL)
Selection Sampling

Description

Given a set of N objects, this program will select n of them at random in an unbiased manner (a simple random style without replacement).

File Name

"SSEL"

Calling Syntax

CALL Sel_sampling (T_number,S_number,X(*))

Input Parameters

T_number	total number of records in the set.
S_number	number of records to be selected.

Output Parameters

X(*)	array of size (1:N) containing the index numbers of the records to be sampled.

Algorithm

To select n records at random from a set of N, where 0<n<=N:

1. Set t=0,m=0.
2. Generate a random number U, uniformly distributed between zero and one.
3. If (N−t)*U>=(n−m), then go to step 5.
   Else go to step 4.
4. Select the next record index for the sample.
   m=m+1.
   t=t+1.
   If m<n then go to step 2.
   Else the sample is complete and the algorithm terminates.
5. Skip the next record index.
   t=t+1.
   Go to step 2.

Special Considerations

1. In order to avoid connections between samples obtained on different runs, care must be taken to use different starting seeds each time this program is run. Both IRND (using SEED) and RND (using RANDOMIZE) allow for this. The seed can either be initialized in the calling program or the subprogram itself.

   A simple way of initializing different seeds for different runs is to do the following: use the digits from the month, day, and time that the program is run as the seed. For example, if you are running the program on June 19 at 9:47 am, then your seed would be .6190947.

Reference

1. Knuth, Donald E., The Art of Computer Programming, Vol. II, Seminumerical Algorithms, Reading, Mass.: Addison-Wesley, 1969, p. 122.

Instructions

1. Insert the GOODNESS-OF-FIT cartridge with the machine turned on.
2. a. Type: LOAD "SSEL",10
   b. Press: EXECUTE
3. The title "SELECTION SAMPLING TECHNIQUE" is printed along with an explanation of how the program works.
4. When "STARTING SEED?" is displayed:
   a. Enter a starting seed for the random number calculations
   b. Press: CONT
5. When "TOTAL # OF RECORDS IN SET?" is displayed:
   a. Enter the total number of records in the set.
   b. Press: CONT
6. When "# OF RECORDS TO BE SELECTED?" is displayed:
   a. Enter the total number of records to be selected.
   b. Press: CONT
7. When complete, the indices of the records to be chosen are printed. Since the actual records may be stored in a variety of formats, you are required to write your own routine to get the actual records themselves.

SELECTION SAMPLING TECHNIQUE

Given a set of N objects, this program will select n of them at random in an unbiased manner.

In order to avoid connections between samples obtained on different runs, care must be taken to use different starting seeds each time this pogram is used. A simple way of doing this is the following: use the month, day, hour, minute that you are starting the program as the initial seed. So, for example, if today were June 19 and it were 9:07am, then your starting seed would be 6190907.

STARTING SEED: 81478

TOTAL # OF RECORDS IN SET: 100
OF RECORDS TO BE SELECTED: 13

RECORDS TO BE SELECTED:
15 16 20 21 22 49 57 67 73 78 88 89 90

(SSHUFL)
Shuffling

(SSHUFL) Shuffling

Description

Given an array of numbers, this program randomly shuffles the array.

File Name

"SSHUFL"

Calling Syntax

CALL Sshuffle(N,X(*))

Input Parameters

N	number of digits in the array to be shuffled.
X(*)	array of dimension (1:N) containing the digits to be shuffled.

Output Parameters

X(*)	array of dimension (1:N) containing the shuffled digits.

Algorithm

Let X1, X2, ..., Xt be a set of t numbers to be shuffled.

1. Set: j=t.
2. Generate a random number U, uniformly distributed between zero and one.
3. Set: k = greatest integer in [j*U+1]. Hence k is a random integer between i and j. Exchange Xk and Xj.
4. j=j−1.
   If j>1 then return to step 2.
   Else the algorithm terminates at this point.

Reference

1. Knuth, Donald E., The Art of Computer Programming, Volume 2 Seminumerical Algorithms. Reading, Mass.: Addison-Wesley, 1969, p. 124-125.

Instructions

1. Insert the GOODNESS-OF-FIT cartridge with the machine turned on.
2. a. Type: LOAD "SSHUFL",10
   b. Press: EXECUTE

3. The title "SHUFFLING" is printed along with an explanation of the options available to you in the program.
4. When "HOW MANY NUMBERS WOULD YOU LIKE TO SHUFFLE?" is displayed:
   a. Enter the number of digits to be shuffled.
   b. Press: CONT
5. When "HOW WOULD YOU LIKE TO ENTER YOUR DATA? [ENTER 1, 2 OR 3]" is displayed:

   a. Enter 1 if each point is to be input individually.

   b. Press: CONT

   c. Go to step 6.

   or

   a. Enter 2 if you wish to enter just the starting value, ending value, and the step size.

   b. Press: CONT

   c. Go to step 9.

   or

   a. Enter 3 if the data is to entered from a stored file. In this case, the data must be stored as a one-dimensional vector.

   b. Press: CONT

   c. Go to step 10.

6. When "X(I)?" is displayed (for I=1 to the number of points to be entered):

   a. Enter X(I).

   b. Press: CONT

   c. Continue with this step until all your points have been entered.

   d. Go to step 7.

7. When "WOULD YOU LIKE TO MAKE ANY CHANGES IN THE DATA: (Y/N)" is displayed:

   a. Enter Y if you would like to make a change in the data.

   b. Press: CONT

   c. Go to step 8.

   or

   a. Enter N if no changes are desired in the data.

   b. Press: CONT

   c. Go to step 11.

8. When "ENTER THE NUMBER OF THE ELEMENT TO BE CHANGED." is displayed:

   a. Enter the index number of the element to be changed.
   b. Press: CONT
   c. Enter the corrected value.
   d. Press: CONT
   e. Go to step 7.

9. When "ENTER STARTING VALUE, ENDING VALUE, STEP SIZE. [FOR EXAMPLE: 10,1000,10]" is displayed:

   a. Enter a starting value, ending value and step size. In the example, these three values would replace entering: 10, 20, 30, ..., 1000.
   b. Press: CONT
   c. Go to step 11.

10. When "ENTER FILE NAME. [FOR EXAMPLE, File:T14 OR Data:F8]" is displayed:

    a. Enter the name of the file from which you want to retrieve the data.
    b. Press: CONT
    c. The data is retrieved from your file.
    d. Go to step 11.

11. After the data has been shuffled, the options available to you at this point in the program will be displayed. When "ENTER YOUR CHOICE. [EITHER 1, 2, or 3]" is displayed:

    a. Enter 1 if you would like the shuffled data printed out.
    b. Press: CONT
    c. Go to step 12.

    or

    a. Enter 2 if you would like the data saved on a mass storage device.
    b. Press: CONT
    c. Go to step 14.

    or

    a. Enter 3 to end the program.
    b. Press: CONT
    c. The program is terminated.

12. When "ENTER THE SELECT CODE OF THE PRINTER." is displayed:

    a. Enter the select code of the printer.

    b. Press: CONT

13. When "ENTER THE BUS ADDRESS OF THE PRINTER." is displayed:

    a. Enter the bus address of the printer.

    b. Press: CONT

    c. The data set is printed on the appropriate device.

    d. Go to step 11.

14. When "ENTER THE FILE NAME. [FOR EXAMPLE: File:T14 OR DATA:F8]" is displayed:

    a. Enter the file name on which you want the data stored.

    b. Press: CONT

    c. The data set is saved as a vector, and the program ends.

```
                              SHUFFLING

   Given an array of numbers, this program will randomly shuffle the digits.
You may enter your vector in any of the following manners:

     1.  Enter each point individually, for example: 5,2,6,4,2,1,5.

     2.  Enter the starting value, ending value, and the step size.
         For example: 1,10,1
         This would be equivalent to entering: 1,2,3,4,5,6,7,8,9,10

     3.  Enter the data from a stored file.  In this case, the data must be
         stored as a one dimensional vector.


# OF ELEMENTS TO BE SHUFFLED:  52

STARTING VALUE:  1
ENDING VALUE:  52
STEP SIZE:  1


   The data has been shuffled.  The choices available now are:

     1.  Print the data out.

     2.  Store the data on a mass storage file.

     3.  End the program.
```

SHUFFLED DATA:

I	X(I)	X(I+1)	X(I+2)	X(I+3)	X(I+4)
1	34.000000	16.000000	24.000000	35.000000	41.000000
6	42.000000	50.000000	26.000000	9.000000	19.000000
11	2.000000	39.000000	48.000000	6.000000	36.000000
16	46.000000	51.000000	21.000000	11.000000	33.000000
21	14.000000	22.000000	17.000000	27.000000	44.000000
26	38.000000	52.000000	47.000000	7.000000	15.000000
31	45.000000	5.000000	3.000000	30.000000	8.000000
36	25.000000	29.000000	32.000000	49.000000	37.000000
41	1.000000	31.000000	43.000000	10.000000	23.000000
46	18.000000	13.000000	40.000000	4.000000	12.000000
51	20.000000	28.000000			

Appendix I

9845 Random Number Generator: RND

This generator uses a modification of the standard "multiplicative congruential generator". In this generator, a starting value called the seed is multiplied by a positive integer constant, and the fractional part of the result becomes the new seed and the next random number in the generated sequence.

The algorithm used in the RND has a starting seed of PI/180=0.017453292520. This seed may be set by the program to any new value by using the RANDOMIZE statement.

In this routine, the value of 29 is used for the multiplier. To prevent undesired properties in the sequences of random numbers generated (i.e., pairwise correlation and non-random trailing digits), two modifications are made to the standard multiplicative congruential generator. First, the algorithm is performed twice before returning the next random number and setting the new seed. Second, two digits from the first application of the method are saved and appended to the end of the result of the second pass. The exact steps used in the algorithm, along with three examples, are presented below.

In general, the method used is not a very sophisticated one, and is intended only to provide a convenient source of random number sequences for such applications as game programs, random pattern generation, random testing sequences, and the like. Anyone doing sophisticated random statistical techniques or Monte Carlo evaluations would almost certainly want to use a random number generator that has been shown to have passed more severe tests for statistical randomness, such as IRND or RSUPER.

The algorithm below is the one used to generate the next random number in a sequence from the previous one (i.e., the seed) using RND:

1. Multiply the seed by 29.
2. Keep the fractional part of the result of step 1.
3. Counting from the first non-zero digit to the right of the decimal point, save digits 5 and 6 for use in step 6.
4. Multiply the result of step 2 by 29.
5. Keep the fractional part of the result of step 4.
6. Counting from the first non-zero digit to the right of the decimal point, replace digits 11 and 12 with the two digits saved in step 3.
7. Save the result of step 6 as the new seed, and return its value as the next random number in the sequence.

Below are three examples of the algorithm. In each case, the seeds chosen and the random numbers generated are from the actual sequence of numbers generated with a starting seed of PI/180.

Seed:	Example 1	Example 2	Example 3	
Step 1:	.017453292520	.382186859051	.315147299705	
Step 2:	.506145483080	11.083418912500	9.1392271691450	
Step 3:	.506145483080	.083418912500	.1392271681450	
	45 ←	89 ←	71 ←	digits saved
Step 4:	14.678219009300	2.4191484462500	4.038879052050	
Step 5:	.678219009300	.419148462500	.038879052050	
Step 6:	.678219009345	.419148462589	.0388790520571	

Appendix II

Uniform Random Number Generator: IRND

By far the most successful random number generators known today are special cases of the Linear Congruential Generator Model. In this model, we choose

X0	the starting value	X0>=0.
A	the multiplier	A>=0.
C	the increment	C>=0.
M	the modulus	M>X0, M>A, M>C.

The desired sequence of random numbers Xn is then obtained by setting

Xn+1=(A*Xn +C)MOD M,   n>=0. This is called a linear congruential sequence.

IRND is based on this linear congruential model. In designing IRND, the following choices were made:

1. The number X0, the starting seed, has been set at PI/180. This means that each time IRND is loaded into the machine, PI/180 is set as the seed. The statement SEED has been provided in the binary to allow you to change this starting value. Each time a new random number is generated, it becomes the new seed.
2. In order to make IRND as efficient as possible, the word size of the 9845 has been chosen as the modulus M. Hence, M=10∧12. In the binary the computation of (A*X+C) MOD M is done exactly with no roundoff error. There is no way to change the value of M.
3. To ensure that the random number generator will produce all M different possible values of X before it starts to repeat and to ensure high potency, A has been chosen so that A MOD 200 =21. In particular, A=314159262221. If another value for A is desired, the ACOEF statement may be used. It is strongly suggested that A be tampered with only if you have an excellent understanding of the linear congruential model.
4. This choice of A along with M=10∧12 has passed the Spectral Test. A number of other values for the coefficient A have also done well on the test.

M=10∧12					
	Cn Values				
A-Coefficient	N=2	N=3	N=4	N=5	N=6
3141 5926 2221	2.708	2.740	1.486	2.120	1.906
3954 6546 5421	2.778	1.407	4.505	1.250	3.735
3141 3574 5221	1.644	1.188	2.498	1.100	2.458
3147 4376 9221	2.006	1.663	1.270	1.095	1.568

5. The constant C has been chosen as 0.211324865407. This may be changed using the binary statement CCOEF.
6. The least significant (right-hand) digits of X are not very random, so decisions based on the number X should always be primarily influenced by the most significant digits.
7. For "high resolution" Monte Carlo applications, it is suggested that the super random number generator "RSUPER" which combines both IRND and RND be used.

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